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EDITORIAL NOTES.

The Whitby Museum.

THE Editor has great pleasure in calling attention to the appeal printed below on behalf of the building fund for a new Museum in his native place. It is well known to all geologists that the Whitby Museum contains an unrivalled collection of fossils from the Lias, among other valuable items. This collection is at present housed in the top floor only of a building most inadequate in size and situated in a very crowded part of the town. The lower part of the building is used for various other purposes, the stairs are narrow, and in case of fire it would be impossible to save anything. The opportunity now offers itself for the construction of a museum worthy of the collections, on a most suitable site, and with accommodation sufficient for their proper display and preservation. The Editor earnestly hopes that many geologists will see their way to send a subscription towards this most laudable object.

The Trustees of the Whitby Museum are issuing an urgent appeal for funds to enable them to build a new house for their great collection of Saurians and other fossils, which is perhaps unequalled by any in the world, and includes Martin Simpson's collection of Ammonites, of which a few, one hundred and seventeen in number, have been illustrated in Mr. S. S. Buckman's work on *Type Ammonites*.

There is probably no other town that has a better collection of local exhibits and relics, including those relating to Captain Cook, the whole being housed in the present most inadequate building where they cannot be properly seen and appreciated.

The site for a new Museum has now been offered by the Trustees of the Pannett Park, adjoining the new Art Gallery, now almost completed. An appeal therefore is made to all who are interested for funds to carry on the work, one thousand pounds being needed in addition to the funds already in the hands of the Trustees.

Any donations forwarded to the Hon. Treasurer, Mr. Charles Wright, Bank Chambers, Whitby, Yorks., will be duly acknowledged.

NORMANBY.
ROBERT B. TURTON.
T. H. WOODWARK.

ORIGINAL ARTICLES.

The Recent Geology of the Northern Fayum Desert.

By Elinor W. Gardner, M.A.

Lecturer in Geology at Bedford College, London; Associate of Newnham College, Cambridge.

(PLATE XI.)

A preliminary account of the subject of this paper was given before Section H of the British Association at the Oxford meeting in 1926 (1, 2).[1]

It was impossible at that time to enter into the question of the faunas of the different lakes that were discovered, but these have now been worked out, and the object of this paper is to give some account of them, together with fuller details of the containing deposits and their new relationships.

The Fayum has been visited and described by various travellers, geologists, engineers and archaeologists from the time of Herodotus onwards. Around it has centred the controversy as to the position and extent of the ancient historic Lake Moeris. This question has been fully dealt with by Hanbury Brown in his book *The Fayum and Lake Moeris* (1892). He attacked the problem from the point of view of the irrigation engineer, and came to certain conclusions from an examination of lake levels, which would seem to require modification in the light of the new evidence collected last season. In 1905 the whole area was surveyed geologically by H. J. L. Beadnell, and a full account of the topography and Tertiary geology may be obtained from his report published by the Geological Survey of Egypt (3).

Little attention was paid by him to the most recent deposits—the lake beds—which had long been known to exist in the area; they were, however, traced up to a height of 74 ft. O.D., and the conclusions reached were substantially the same as those of Hanbury Brown; namely, that in Pleistocene times the Nile gained access to the Fayum, probably as it was cutting its bed downward, and filled the depression to a height of some 74 feet O.D., covering an area of about 868 sq. miles—about ten times the size of the modern lake. Beadnell considered that the connexion with the Nile may have been broken, but that it was re-established as the river built up its bed, and the resulting high level lake eventually came under control in XIIth Dynasty times, and was known as Lake Moeris.

Beadnell further states that in the sub-fossil lake fauna there is a complete absence of White Nile forms such as *Ampullaria*, *Lanistes*, etc., that it shows more affinity with the Blue Nile, and that *Hydrobia stagnalis*, at present living in the modern lake, does not occur in the old deposits (4).

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[1] Figures in parentheses refer to Bibliography at end of paper.

The evidence obtained last season would seem to require a different interpretation of the connexion of Lake Moeris and the prehistoric lake, and further investigation has shown that the above statements as to the fauna were based upon insufficient collecting.

TOPOGRAPHY.

The Fayum Oasis is a saucer-shaped area, the rim of the saucer being broken on the southern side by a channel some eight miles long, which communicates with the Nile Valley at El-Lahun. The bottom of the saucer is asymmetrical, the deepest part being towards the northern side, where a brackish lake, the Birket-el-Qerun, lies at a height of 148 feet below mean sea level at Alexandria (December, 1925). The long axis of the lake, about 25 miles, trends east and west, the breadth is some 5 miles at the widest part, and the depth nowhere more than about 28 feet. To the south, towards the Nile Valley, the land rises gradually in three plateaux. The highest of these lies between 82 and 74 feet, and the edge of it is just north of Medinet-el-Fayum. From there the second plateau slopes gradually down to the neighbourhood of Sennures at 33 feet, the third extends to the lake. Most of this southern side is under cultivation, its surface being irrigated by the waters of the Bahr Yusuf, a stream which takes off from the Nile at Assiut some 200 miles to the south, and turning at right angles at Lahun, enters the Fayum by the aforementioned channel.

The features of special interest on the southern side are the two deep ravines, which branch off from the Bahr Yusuf south of Medinet-el-Fayum, one on the east and the other on the west side, and a conspicuous sandy bank running more or less east and west just north of the highest plateau between Edwa and Biahmu (see map).

To the north of the lake the land rises much more abruptly in a series of alternating scarps and plateaux to the level of the Sahara, 1,000 feet above sea level. From the western end of the lake for a distance of about 15 miles a steep Tertiary scarp lies close to the Birket-el-Qerun. Just west of Dimê, however, this scarp turns northward and forms the western boundary of the lake beds, which here spread out over a lower plateau and sweep inland from the Birket-Qerun in a big bend for about 5 miles.

The surface of this lower plateau is irregular, being broken by isolated hills, especially in the south-west, and numerous more or less disconnected basins. Near its southern edge lies the old Graeco-Roman town of Dimê, the base of mounds surrounding it being at 53 feet O.D. A few miles to the east the scarp swings abruptly northward and is bordered by low-lying land covered with sand and tamarisks, which stretches to the foot of Qasr-es-Sagha, a XIIth Dynasty temple some 4 miles north of Dimê at 115 feet O.D. This feature, which has not hitherto been noted, is of great importance in considering the height of the lake in the historic period when the old towns were inhabited, for it would carry the waters of a lake as low as 0 feet O.D., right up to the foot of the cliffs on which the temple stands.

On the eastern side of this depression, named by us Moeris Bay, the Tertiary scarp again runs north and south, and then turns and follows the direction of the lake, though not bordering it so closely as on the western side.

This eastern plateau on its northern side is, like the western, broken up into a series of depressions running roughly east and west. This is doubtless due to the slight northerly dip of the Tertiary rocks. The surface is smoother, with less rock exposed than on the western side, and the rise to the Tertiary scarp is more gradual. The main line of cliffs again swing northward, and the ground to the south of them falls gradually to the old lake level in most places, though broad shallow wadis cut through it on the eastern and western sides.

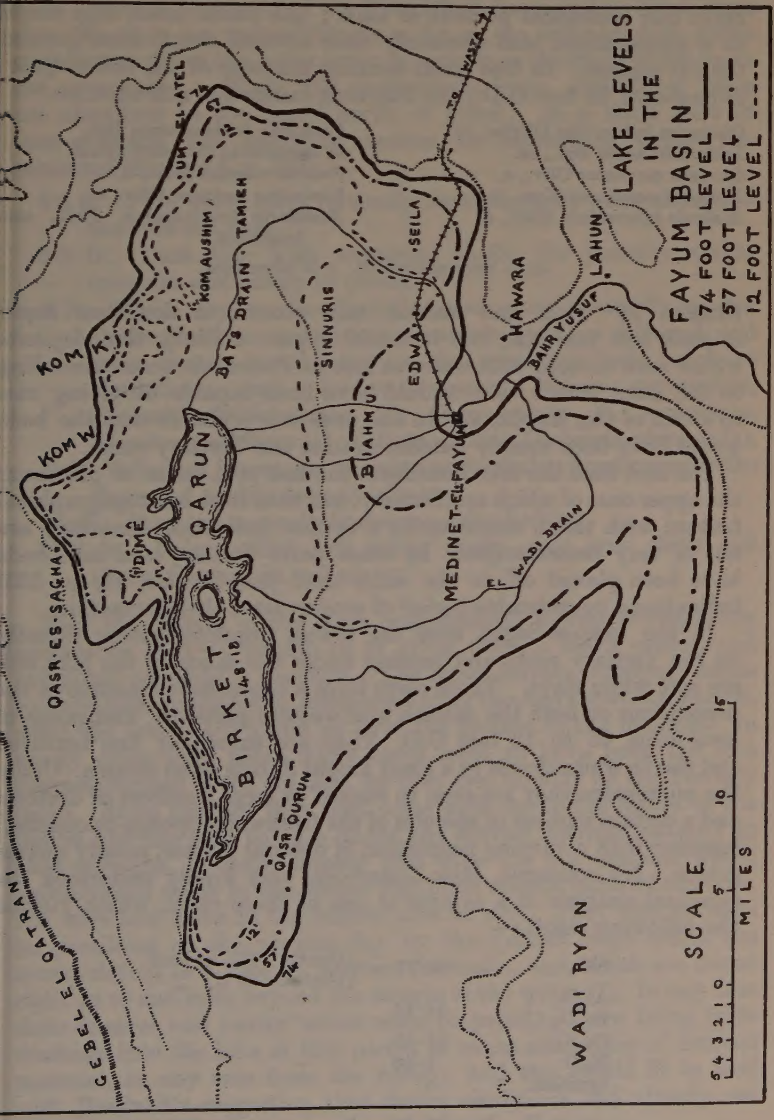
It was on these eastern and western plateaux that the greater part of the geological work was done, and it soon became evident that the story was not a simple one of the rise and fall of one sheet of water, but that two lakes or more were involved.

The Old Lake.

The first conclusion of importance was that the 74 foot lake was an old one, which had dried up long before the historic period, and could not therefore have been the ancestor of Lake Moeris.

Part of the evidence on which this is based is archaeological and must be briefly referred to. Flint implements of Neolithic type had long been known to occur on the lake beds, but when their distribution was examined in detail by Miss Caton-Thompson in 1924, it was found that they showed a definite concentration in certain areas. These were invariably marked by the presence of stacks and mounds of lake deposit, and it was obvious that the owners of the implements had gathered around these groups of isolated blocks, probably for shelter; in some cases they had even placed their pots on convenient ledges in the mound (5). *These stacks of lake deposit were, therefore, in existence as such in the days of these flint-using peoples*, and since the base of the mounds is approximately at the height of 40 feet, it follows that the lake cannot have been at its maximum height, the hitherto supposed height of Lake Moeris, in their day. Not only so, but it must have dried up sufficiently for the deposits to have been hardened and eroded before their advent. These people are unquestionably earlier than the XIIth Dynasty folk, and therefore the 74 ft. lake cannot have given rise directly to the artificially controlled sheet of water of that time.

These groups of old lake deposits are particularly well seen in the Qasr-es-Sagha area, where they form sites *N*, *O* and *T* to the west of the temple. Traced to the east, as the ground falls and is more sheltered from the north-west winds, the lake deposits form a small continuous plateau, bounded by a steep cliff some 40 feet high (Section I, p. 393). This plateau lies below the temple and is covered with limestone and other rock fragments; it can be traced for some



distance northward, following the margin of Moeris Bay, but has been destroyed by erosion on the eastern and western sides.

The beds consist of fine yellow and white sands with alternating clays and occasional pockets of loam; the whole series dips south at a gentle angle, and obviously once covered much more ground than at present. In fine sands forming the base of the cliff at Qasr-es-Sagha at 28 feet O.D., the following fauna was collected :—

Cleopatra bulimoides Olivier, cc.
Isidora truncata Bgt., cc.
Lanistes carinatus Oliv., c.
Limnaea natalensis Krss., c.
Melania tuberculata Müll., c.
Planorbis bridouxianus Bgt.
P. mareoticus (Letour) Innes.
Valvata nilotica Jick., c.
Viviparus unicolor Oliv., c.
Nodularia teretiusculus, Phil., one fragment.

cc = very abundant. c = abundant.

Erosion by wind and sudden rain storms is doubtless rapid in such soft material, but it would appear unlikely that deposits which were covered with water as late as Ptolemaic times, according to the Lake Moeris view, should have been capable of giving rise to a cliff of this height, and in this case it is probable that the beds would have been steeply banked against the Tertiary rocks.

The fact that the lake beds form the last of a series of plateaux, the upper ones of which are Tertiary, and thus form one topographical feature with them, seems to be a further indication that they are not of very recent origin. In other parts Tertiary and lake beds have been planed off to the same level (see Section II, p. 393) indicating a considerable period of erosion since their formation.

In the Qasr-es-Sagha area the lowest deposits resting directly on the Tertiary rocks and passing under the sands of the lake cliff are soft white clays. These clays form a conspicuous feature of the depressions on both the eastern and western plateaux, and range in level from 46 to 12 feet O.D. They are extremely fine textured and rise in white clouds to a great height during wind storms. Under the microscope they are seen to consist of large numbers of diatoms and a certain number of spicules of the freshwater sponge Spongella,[1] together with a varying proportion of detrital matter, mostly quartz grains. My colleague, Miss Lederboer, very kindly undertook the chemical analysis of a sample of one of these clays, which yielded the following result :—

SiO_2	60·77	= Quartz 10%, approx. Diatoms 50%, ,, .
Al_2O_3 Fe_2O_3	14·14	
$CaCO_3$	15·45	
MgO	1·46	
Ignition	8	
	99·82	

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[1] I am indebted to Mr. R. Kirkpatrick of the British Museum for this determination.

Similar diatom clays were noted by de Morgan (6) and referred to by M. Blanckenhorn around Dimê, where they frequently weather into low asymmetrical mounds, the steep side facing the prevailing wind. Over a large part of the West Dimê Basin and in other areas also, the clays are unfossiliferous so far as the ordinary lake forms are concerned, but the latter occur in pockets as the edges of the basin are approached. Shells and particularly large *Ampullaria ovata* are abundant in the basin north of Dimê; in a shaft west of Qasr-es-Sagha the following section in descending order was measured (Section I, p. 393):—

9·5 ft. Pure white clay, vertically fissured, shells more abundant towards the base.
2·2 ft. Dark clay with numerous shells, the junction rather irregular and sandy in places.
·8 ft. White clay, sandier than that above, and decidedly sandier at the junction, containing numerous *Limnaea cailliaudi* and other types found also in the overlying beds, such as *Ampullaria ovata*, *Isidora truncata*, *Melania tuberculata*, *Planorbis bridouxianus*, *P. alexandrinus*, *P. mareoticus*, *Theodoxus niloticus* (1), *Valvata nilotica*, *Corbicula africana* (1).
·9 ft. Yellowish limestone, showing an irregular junction with the clays and rubbly towards the top.
2·1 ft. Grey green sandy limestone, false-bedded.
16·8 ft. False-bedded soft white sands, pale grey clays and alternating sands and clays.

Near the margin of the clays carbonaceous matter is frequently present to such an extent as to given them a black colour, and polygonal cracking is common. The latter feature, however, seems to have been produced in some cases after the clays were weathered, since the cracks are found all over the surface of the mounds. In nearly every case these white clays seem to have been the first deposits formed in the old lake, for they rest directly on the Tertiary rocks. From the fact that they come right up to the shores of the basins and are seen to pass under the coarser detrital material at Qasr-es-Sagha, it would appear that they are not deposits which accumulated solely in the deeper and more remote parts of the lake, but were laid down in the littoral area as well. They may perhaps be paralleled at the present day by the diatom clays which are accumulating in a lake in Western Australia, and which are found right up to and even beyond the margin of the water (7). In any case their fineness and purity would seem to point to there being little drainage into the lake at this period to cause admixture of detrital material, at any rate from the north; and this would fit in well with Beadnell's suggestion that desert conditions had already set in when the Nile first gained access to the Fayum.

The possibility of the absence of coarser deposits being due to peneplanation of the surrounding country is ruled out both by the topography of the region to the north of the clays at Qasr-es-Sagha and by the absence of any sign of movement subsequent to their deposition to account for the change in character of the overlying beds.

The 40 feet of coarser material which overlies the diatom beds at Qasr-es-Sagha is certainly derived from local Tertiary rocks to the north—in the absence of fossils it is at times indeed hard to distinguish one from the other—and this must indicate a period of greater normal erosion and therefore presumably of greater rainfall. Again, the thickness of the deposits would seem to point to a considerable period for their formation.

Until the beds on the south side of the lake have been fully worked out and followed into the Nile valley the age of these deposits cannot be fixed. They are presumably Pleistocene, but how long this episode lasted cannot at present be calculated.

It is probable that there were fluctuations in the level of this old lake, but eventually it dried up. There is as yet no evidence as to whether the desiccation was complete or not, or as to the causes which brought this about, though a possible explanation is that suggested by Beadnell that the Nile was deepening its bed more rapidly than was the case with the Bahr Yusuf.

The Neolithic Lake.

At some later period a second lake came into existence and reached a maximum level of 57 feet O.D. This may be called the " Neolithic " lake since it is clearly closely connected with the sites of the Neolithic flint-using Fayum people.

Some of the most striking evidence for the existence of this second lake is provided by the fauna and its distribution. On both the eastern and western plateaux the following species were found, generally in sands resting directly on the Tertiary rocks :—

Bithinia goryi Bgt.
B. cf. *badiella* (Parreyss.) Küster.
B. senaariensis Parreyss.
B. cf. *tilhoi* Germ.
Cleopatra pirothi Jick., cc.
C. bulimoides Oliv.
Segmentina angusta Jick.
Isidora truncata (Fér.) Audouin.
Lanistes carinatus Oliv.
L. carinatus var. *perfecta* Pall.
Limnaea natalensis Krauss.
Melania tuberculata Müll., cc.
Planorbis alexandrinus Ehr.
P. ehrenbergi Beck.
P. bridouxianus Bgt.
P. mareoticus (Letour) Innes.
Theodoxus niloticus Reeve, cc.
Valvata nilotica Jick., c.
Viviparus unicolor Oliv.
Aetheria elliptica Lam.
Corbicula africana Krauss, cc.
Chambardia locardi Bgt., c.
Mutela nilotica (Fér.) Sow., c.
Nodularia gaillardoti Bgt.
N. teretiuscula Phil.
? *Unio niloticus* Caill.

These sands and their associated fauna are not at all conspicuous as a rule, they were often only discovered after careful search, preserved under the overhanging ledges of Tertiary rock and sometimes in the cracks and hollows of the limestone and sandstone

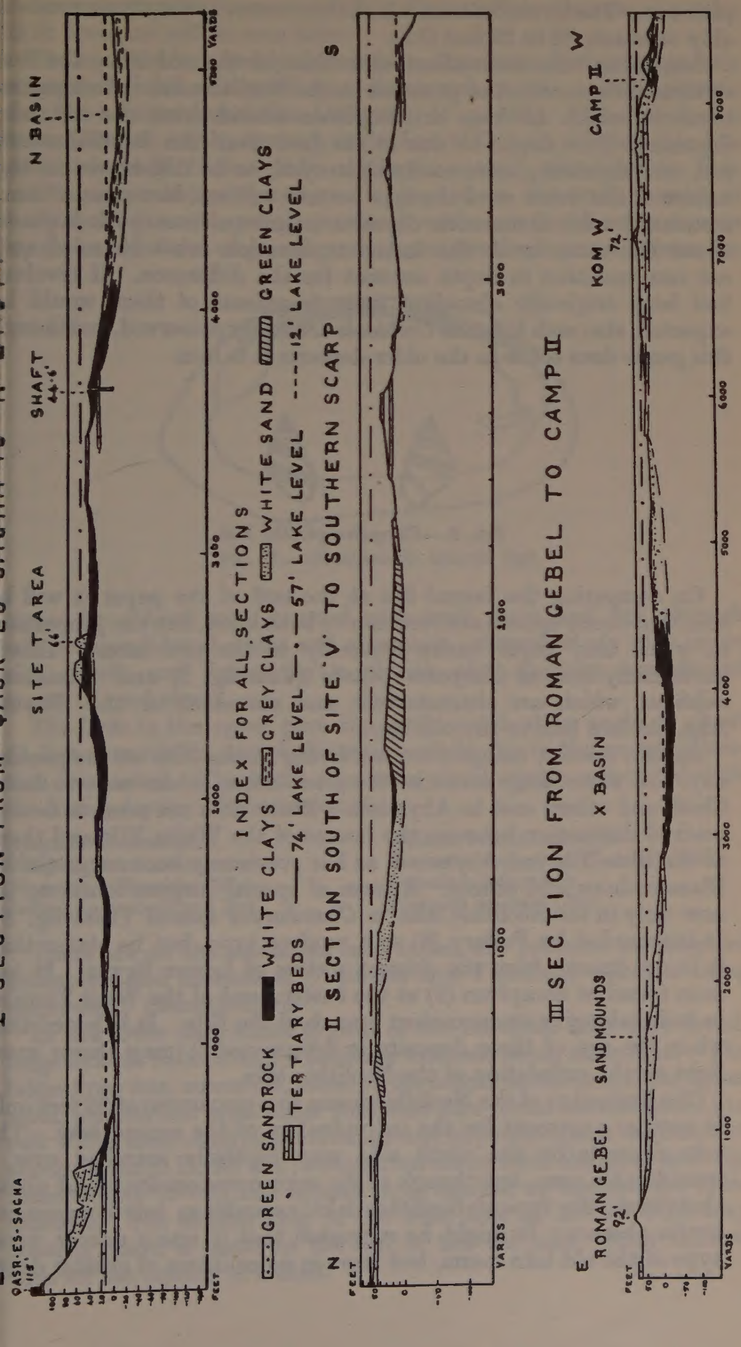
QASR-ES-SAGHA 115'
SITE T AREA 66'
SHAFT 44.6'
N BASIN
FEET
1000
2000
3000
4000
5000 YARDS
INDEX FOR ALL SECTIONS
GREEN SANDROCK
WHITE CLAYS
GREY CLAYS
WHITE SAND
GREEN CLAYS
TERTIARY BEDS
74' LAKE LEVEL
57' LAKE LEVEL
12' LAKE LEVEL
II SECTION SOUTH OF SITE 'V' TO SOUTHERN SCARP
N
S
FEET
50
0
-50
-100
YARDS
1000
2000
3000
4000
III SECTION FROM ROMAN GEBEL TO CAMP II
E
W
ROMAN GEBEL 92'
SANDMOUNDS
X BASIN
KOM W 72'
CAMP II
FEET
50
0
-50
-100
YARDS
1000
2000
3000
4000
5000
6000
7000
8000

FIG. 1.

plateaux. The levels between which they occur, however, are remarkably constant, 52 to 22 feet O.D.

Comparing this association with that of the old lake, the first obvious difference is the presence in the Neolithic lake of numerous bivalves, which are rare or altogether absent from the old lake deposits. This might be due to the fact that the lamellibranchs are, on the whole, more easily destroyed, or to differences in the nature of the water or of the lake bottom. Since, however, a fauna associated with arenaceous deposits is known from both lakes at about the same level, the latter explanation must be ruled out, nor can variation in depth account for the difference. If bivalves had been originally abundant more fragments of them would be expected, also such forms as *Corbicula* are easily preserved, and though this genus does occur in the older deposits it is rare.

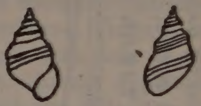

FIG. 2.—*Cleopatra pirothi* Jick.

On comparing the faunal list at the end of the paper it will be seen that many species are common to both lakes, but the proportion in which they occur varies markedly in the two cases. This is particularly true of *Cleopatra pirothi* (Text-fig. 2) and *Theodoxus niloticus*, which are characteristic and abundant in the Fayum lake, but are rare in the old lake.

All the species, except two, are living in the Nile at the present day, and some range south to the great lakes, others west to Lake Chad, and others east to Abyssinia. There does not seem to be any marked distinction between the faunas of the White Nile and those of the Blue Nile and Abyssinia, as has previously been suggested by Blanckenhorn and others. A form of special interest found up till now only in the Neolithic lake is *Chambardia locardi* (Text-fig. 3). It is regarded by Pallary (8) as a modern type, but he states that it is not known from the present waters of Lower Egypt. It has been found at Serapéum (9) at the eastern end of the Wadi Tumilat in beds belonging to an ancient branch of the Nile. It is hoped that when the age of these deposits is determined it may throw some light on the correlation of the Neolithic lake.

The limitation of the Neolithic fauna to a maximum of 52 feet only is another argument for the individuality of the second lake. The lake deposits on the north side were carefully searched over a considerable area, but though shells were occasionally found above that level, the typical Neolithic lake assemblage was conspicuous by its absence. It might be suggested that it was a deeper water type of the old lake fauna, but there is no evidence of greater depth and a considerable amount to show that a shore line was near the 52 ft. level, as will be seen later.

The conclusions already drawn from the above facts were greatly strengthened when a wadi was discovered on the eastern plateau near the western end of Site *L* (Section IV, p. 397). The wadi drains from north to south, starting at 58 feet O.D. and merging into the general level at 17 feet O.D. It is cut entirely through lake beds and has two distinct parts, an upper, where the walls consist of fairly hard greenish yellow sandrock with occasional carbonaceous layers and lenticles of gravel, and a lower portion separated from the upper by a level area covered with wadi wash and cut through soft unconsolidated white and cinnamon coloured sands with minor clay bands, and floored by a whitish clay showing iron-stained traces of reed stems.

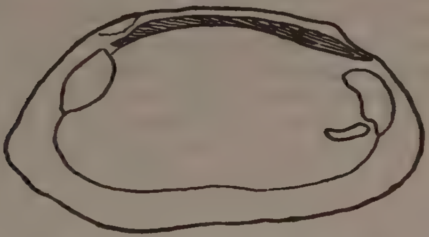

FIG. 3.—*Chambardia locardi* Bgt.

The beds in the upper part dip gently south at an angle of about 4°, but towards the top of the wadi a slight dip in the reverse direction was noted. The fauna was scanty and mostly associated with the loamy layers. It consisted of :—

Ampullaria ovata Oliv.
Bithynia, broken fragment.
Cleopatra bulimoides Oliv.
Isidora truncata (Fer.) Bgt.
Melania tuberculata Müll.
Planorbis mareoticus (Letour) Innes.
Valvata nilotica Jick.
Vivipara unicolor Oliv.

These are on the whole old lake types, the presence of *Cleopatra bulimoides* and absence of *C. pirothi* and *Theodoxus niloticus* being particularly characteristic.

In the lower part shells typical of the Neolithic lake were found, large *Mutela nilotica* and *Theodoxus niloticus* being abundant. The latter type was, moreover, found in the cracks on the side of the upper wadi, and further west other Neolithic lake forms were collected in a soft white sand overlying hardened and gypseous green sandrock at about 54 feet O.D. As will be seen from the section, the lower beds dip more steeply (6°–8°) and appear to be banked up against the older deposits. The sudden drop in the wadi floor at 30 feet O.D. may possibly mark a pause in the fall of the old lake, which allowed time for the cutting of a shelf.

In this section, therefore, the evidence for the separate identity of the Neolithic lake and its overlap on to the older beds is particularly clear, but it can also be seen in a section near Dimê (Section V, p. 397).

To the south of the mounds surrounding the ruins is a small limestone plateau, which terminates rather abruptly at a height of 57 feet. Immediately below this scarp at about 52 feet the typical Neolithic lake fauna was found associated with a fine sand. As this was traced south it was found to overlie hard gypseous green clay with no shells, while further east the same fauna was discovered in a small hollow in the limestone plateau itself at a height of 49 feet.

Between the base of the Dimê mounds and the 57 foot scarp there were a few isolated hummocks of detrital material, which were found to consist of roughly weathered angular blocks of limestone and other material, strongly suggestive of scree origin. Below the scarp the ground slopes gradually down from 50 feet to 35 feet over a distance of 1,267 yards, till the edge of the Tertiary scarp bounding the lake is reached. The plateau is not continuous but is broken towards the south by a shallow basin, the northern rim of which, lying at about 37 feet, is composed partly of lacustrine and partly of Tertiary deposits. Still more interesting was the discovery of a small isolated flat-topped gebel (*D* ii c); this had obviously formed part of the plateau and consisted entirely of lake beds (Section V*a*, p. 397).

These could be separated into two well-defined series, an upper consisting of soft grey clays, brown loams and coarse limestone gravel, resting on a lower deposit of extremely hard green clay impregnated with gypsum.

The upper series contained the following fauna :—

Bithynia cf. *tilhoi* Germ.
Cleopatra pirothi Jick.
Lanistes carinatus Oliv.
Melania tuberculata Müll.
Planorbis mareoticus (Let.) Innes.
P. alexandrinus Ehr.
Theodoxus niloticus Rve.
Valvatus nilotica Jick.
Isidora truncata (Fer.) Audouin.
Limnaea cailliundi Bgt.
Corbicula africana.
Spatha, or Mutela fragment.
Ampullaria ovata Oliv.
(in loams).

The lower series was without fossils, except for a few small *Planorbis.*

Fifty yards or so to the north-east all the typical Neolithic lake types were found well preserved in cracks in the Tertiary sandstone at 37 feet, which here forms the edge of the above-mentioned basin.

As can be seen from the section, a somewhat similar succession is found on the plateau itself immediately to the north of this exposure, and there was a certain amount of evidence that the gravel had once spread further east and south.

The gravel itself is composed almost entirely of flat, more or less oval pebbles of local Tertiary limestone, and though occasional quartz pebbles are present, flint is conspicuous by its absence. The deposit would seem to have been laid down by a stream draining a small wadi, probably to the north-west, since a similar gravel

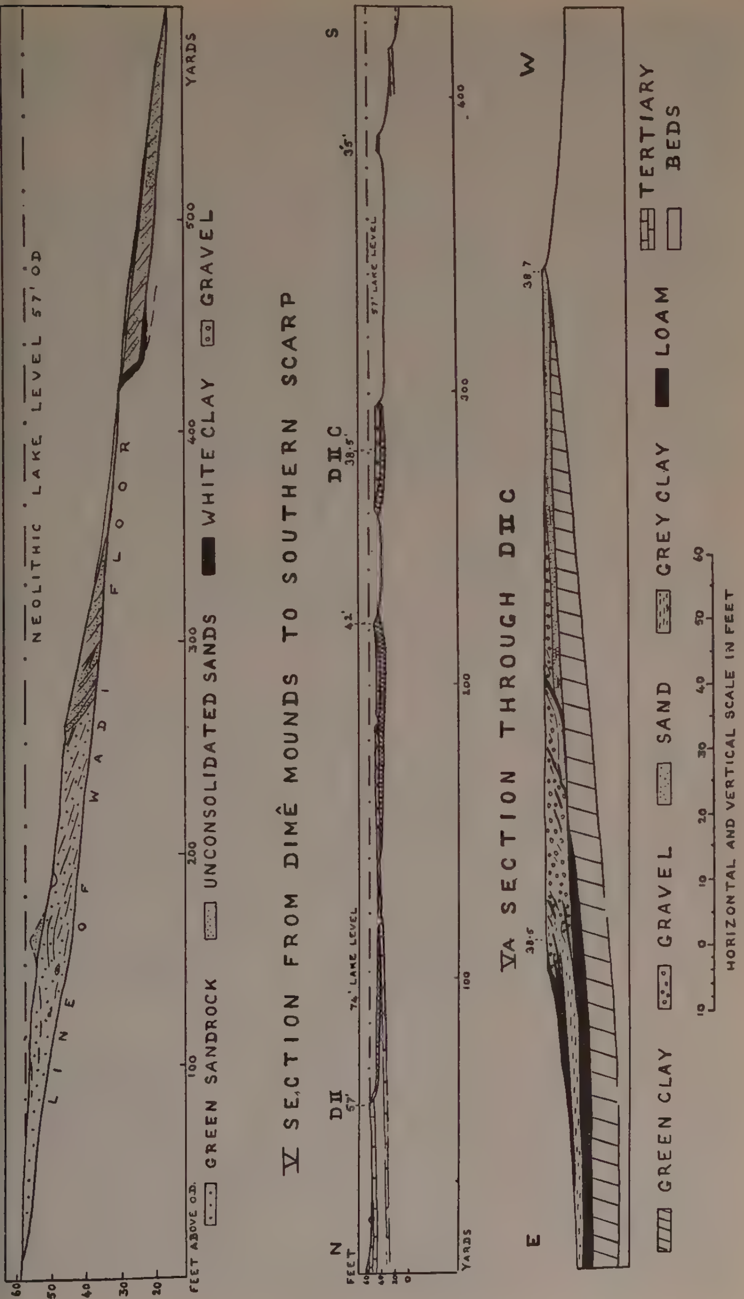
NEOLITHIC LAKE LEVEL 57' OD
LINE OF WADI FLOOR
FEET ABOVE O.D.
60
50
40
30
20
100
200
300
400
500
YARDS
GREEN SANDROCK
UNCONSOLIDATED SANDS
WHITE CLAY
GRAVEL
V SECTION FROM DIMÊ MOUNDS TO SOUTHERN SCARP
N
S
D II
57'
74' LAKE LEVEL
41'
D II C
38.5'
57' LAKE LEVEL
35'
FEET
60
40
20
0
YARDS
100
100
200
300
400
VA SECTION THROUGH D II C
E
W
38.5
38.7
GREEN CLAY
GRAVEL
SAND
GREY CLAY
LOAM
TERTIARY BEDS
10
0
10
20
30
40
50
60
HORIZONTAL AND VERTICAL SCALE IN FEET

Fig. 4.

was found underlying the paved structure at Dimê. The angle of dip and the character of the deposits leads to the conclusion that the stream flowed into standing water at the 38 ft. level and built out a small delta on the edge of which the plants flourished that gave rise to the loam.

The occurrence of a gently sloping plain between the 50 ft. and 35 ft. level was noted in other areas also, namely on the Eastern Plateau south of Site *V* and further east on the same line, where lacustrine and Tertiary beds were again found planed off to the same level (see Section II). The close association of this surface with the deposits of the Neolithic lake, as seen at Dimê, leads to the conclusion that the Neolithic lake itself was in all probability responsible for its formation and that it marks a period when the waters were falling so slowly that sufficient time was available for the cutting of such a platform. That it is not a feature due primarily to subaerial erosion is shown in the occurrence of the lake beds, on the windward as well as the lea side of the Tertiary rocks. From the fact that this plain of erosion has undergone considerable denudation it may be inferred that it is not of very recent origin. When Lake Moeris was drained in Graeco-Roman times about 250 B.C. to allow of land for settlement the climate was probably not very far removed from that of the present day, and it seems unlikely that there has been sufficient rainfall since then to produce the observed effect.

Somewhat similar conclusions were reached from a study of the ground south and south-east of Kom W. A conspicuous feature of this region is a gravel covered area lying between Kom W and the southern Tertiary scarp. The highest part is at the western end and in this region—south of Camp II—a gravel together with a coarse sand containing some of the characteristic Neolithic lake types occurs overlying unfossiliferous green and brown clays. Traced to the east, the overlying deposits split up and finally die out altogether, but what would appear to be a channel draining from this higher ground to the depression to the east was found cutting through the green clays in an east-west direction. This channel is only 37 feet wide and about 2 feet deep, but it is filled with a fine sand containing Neolithic lake types and would therefore seem to indicate a stage in the fall of the second lake.

Further evidence for the existence of a later lake at the 57 ft. level is provided by the change of slope which is very constantly found at that level (see Section III, p. 393), and correlated with this is the occurrence of sandy mounds covered with cylindrical objects resembling roots mineralized by carbonate of lime. Sometimes the latter appear to radiate from a thicker central stem-like process, and though it is possible that they are of concretionary origin the general impression is that they are in some way associated with the former presence of vegetation.

The shores of the present lake are bordered by a line of tamariskcovered sand-dunes, but further from the water the tamarisks die out and eventually only roots and stumps are left projecting from the eroded dunes. The very constant level at which these mounds occur, the base averaging 50 feet and the top being some 6 to 8 feet higher, and their localization along a very definite line, leads to the supposition that they too are the remnants of the old dune line, which once bordered the Neolithic lake.

This supposition is strengthened by the frequent association of these mounds with the bones of animals—elephant, hippopotamus, etc.—such as would be expected along an old shore line. If this be true, the narrowness of the line would seem to indicate that arid conditions prevailed except close to the water's edge, a conclusion strengthened by the relatively small amount of deposit belonging to the Neolithic lake and also the total absence, up to date, of any and shells among the freshwater fauna.

A fringe of vegetation around the lake is further indicated by the occurrence of thin loams at levels between 56 and 35 feet and the presence of carbonized and calcified reed stems.

LOW LEVEL LAKE.

A certain amount of evidence was accumulated for the existence of a more recent lake, either independent of the Neolithic lake or a definite stage on its fall. This lake, which was probably historic, reached a maximum of 12 feet O.D., but its deposits have not so far been found in conjunction with those of the Neolithic lake. The material is found banked up steeply against the Tertiary rocks in the sheltered parts of the scarp bounding the eastern and western plateaux, but even under the most favourable conditions t is of very limited occurrence. It is on the whole coarser and less weathered than the Neolithic lake material, consisting of angular ragments of local Tertiary rocks, or sometimes, at lower levels, riable dried mud. Associated with these deposits is the following auna :—

Bithynia senaariensis Parrys.
Cleopatra bulimoides Oliv.
Isidora truncata (Fer.) Audouin.
Melania tuberculata Müll.
Planorbis mareoticus (Let.) Innes.
Planorbis ehrenbergi Beck.
Paludestrina peraudieri Bgt.
Theodoxus niloticus Rve.
Valvata nilotica Jick.
Corbicula africana Kres.

Theodoxus niloticus is abundant, and in this feature the assemblage ecalls the Neolithic lake fauna rather than that of the old lake. Further, it will be noted that *Paludestrina* occurs here and has been ecorded as high as — 30 feet. This species is at present living in he brackish waters of the lagoons near Alexandria and in the slightly aline waters of the Birket-el-Qerun (10).

The state of preservation of the shells differs markedly from that f the older faunas; they are much fresher in appearance, the riginal colour being frequently preserved and the associated ish bones are white, while those of the older beds are invariably brown and ancient in appearance. Shells and bones in this state of preservation have, up till now, never been found at higher levels either alone or intermixed with the fauna of the older deposits, though derived specimens of the latter ocasionally occur in the lower beds. This gives an additional reason for believing that the higher levels have not been covered by lake water in very recent geological and relatively recent historical times.

Another small point, not without significance in this connexion, is the fact that modern reed stumps have not been found above 10 feet O.D., and then always on the outer edge of the eastern and western plateaux, never in the enclosed basins, which were presumably cut off from the main body of water and had very possibly dried up. At various levels below 12 feet, notably at — 68 feet, reed banks crowded with *Theodoxus* and *Planorbis*, etc., occur in a similarly fresh state of preservation, and shells of the same type but still fresher in appearance are found right down to the marshy flats surrounding the present lake.

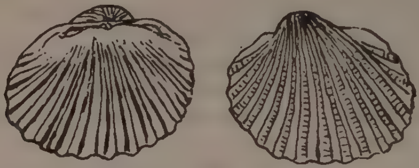

Fig. 5.—*Cardium edule* var. *clodiensis* Ren.

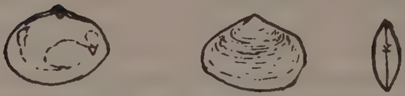

Fig. 6.—*Scrobicularia cottardi* Payr.

The fauna of this as recorded in various publications (11) seems to be of the same type as that of the 12 ft. lake, but two new brackish water forms were collected from the shores of the Birket-el-Qerun, which were not found in any of the older lake deposits and which have not been recorded before from this neighbourhood. These are *Cardium edule* var. *clodiensis* and *Scrobicularia cottardi* (Text-figs. 5–6), both brackish water Mediterranean types, and though the animal was not found living in them, their mode of occurrence and state of preservation makes it difficult to avoid the conclusion that they are at present living in the Birket-el-Qerun, and have been introduced there in relatively very recent times, for neither Blanckenhorn, who collected along the shores of the lake in 1900, nor Mr. Cunnington's expedition in 1908 make any mention of them, though they are now among the most abundant types to be found along the shore (12).

Blanckenhorn in discussing the origin of the *Paludestrinas* (? *Hydrobia*) in the Birket-el-Qerun suggests that they were introduced on the feet of the aquatic birds which are so abundant in the neighbourhood. This explanation seems to be the most probable for the introduction of the new types also, since none are known in the Nile Valley itself; for since the lake is gradually becoming salter and salter, any brackish water form accidentally introduced would find the conditions becoming gradually more favourable.

It is of interest to note that the presence of *Cardium edule* in the schotts of Tunisia and Algeria, together with *Melania tuberculata* and other freshwater forms, was at one time considered as evidence of the former presence of the sea in that region, but this idea was given up on various grounds and Tournouër (13) in 1878 suggested that their occurrence was due to transportation by birds. The Fayum evidence appears to be in entire agreement with this view.

BATS DRAIN.

Little time could be given to the study of the lake beds on the south side of the Birket-el-Qerun, but the few days spent in the examination of the Bats Drain near Edwa yielded some interesting evidence, which, so far as it goes, supports the conclusions reached from a study of the deposits on the north side. The ravine is about a quarter of a mile wide and the stream meanders along the floor of salty alluvial deposit some twenty feet below the general level of the country, which is here between 27 and 37 feet above O.D. The sides of the ravine are steep, and are composed of Tertiary rock (the Ravine Beds) overlain irregularly by lake deposit, which s for the most part quite as hard as the underlying material. The owest lake beds consist as a rule of rather coarse sand with fairly arge quartz and flint pebbles, followed by finer sands and clays, he latter frequently hard and gypseous. The sand is often wind blown and the flints thermally fractured, indicating that desert conditions were in existence before the formation of these deposits. n a pinkish-brown clay south of the Seila-Edwa road, at a height f 19 feet O.D., numerous *Paludestrinas* were found, but no other ossils at this level. They also occurred in consolidated coarse sand t about the same level north of the road, while in other places eds resting directly on the Tertiary rocks contained *Corbicula*.[1] t is suggested provisionally that this impoverished fauna may epresent the last stages in the drying up of the old lake.

Passing along the drain, the cliffs are found to be topped sometimes y lake beds and sometimes by Tertiary rocks. This feature may be compared with their planing off to the same level already noted on the north side of the lake. That the story of the formation of these lake deposits was not a simple one can also be seen in several places in the section examined. This is illustrated by the accompanying diagram of the side of a small lateral wadi coming into the main drain on the left bank. The upper beds are of pale grey clays about 10 feet thick, underlain by darker clays, both being practically horizontal and resting at the eastern end on Ravine Beds fuel of gypsum. Some 6 yards further west a second series of still darker clays underlies the first, but dips at 22° west and thins out against the Tertiary rocks to the east. In these clays are narrow iron-stained bands showing small contortions, and near the base were found numerous pebbles, some of flint and some of coarse cemented wind-blown sand very similar in appearance to that occurring in situ in another part of the main drain.

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[1] Blanckenhorn notes shells of Neolithic lake type from Bats at railway crossing (op. cit., 1921, p. 161).

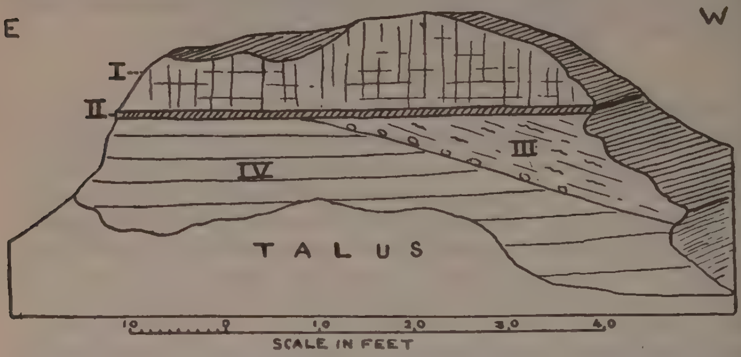

Fig. 7.—Cliff Section in Bats Drain. I, Pale Grey Clays; II, Dark Grey Clays; III, Dipping Clays; IV, Ravine Beds.

Whatever may be the final interpretation of this story, it seems evident that two theories frequently met with in regard to this drain must be discarded. Firstly, the drain appears to be of perfectly natural origin and of some antiquity, not an irrigation drainage channel from the overflow of Lake Moeris, as Hanbury Brown and others have supposed. Secondly, the material forming this northern edge of the highest plateau is not Nile mud of the type carried at the present day, but, as Blanckenhorn has suggested, a much coarser and more arenaceous deposit, brought in and built out as a delta at a time when the Nile was flowing faster and carrying different material. A third misconception shared by Hanbury Brown and various archaeologists is that the Edwa bank is an artificial one, raised probably in the XIIth Dynasty to dam back the waters of Lake Moeris from the highest plateau.

A most cursory examination of this bank where the road cuts through it at Edwa shows that it is formed of well-bedded material, and the 6 inch contour map indicates very clearly that it is nothing more than a remnant of the highest plateau which continues for some distance east of Edwa. From Schweinfurth (14) onwards its natural origin has been noted by all geologists who have seen it.

The Bats and El Wadi drain point to the existence of a period of considerable vertical erosion some time after the formation of the first lake and most probably during the fall of the Neolithic lake. Evidence of a similar type was obtained at the west end of the Birket-el-Qerun, where a wadi was found cutting the lake beds from 65 feet to — 8 feet O.D. After its formation this wadi had been filled with coarse yellow sand washed down from the neighbouring hills, and after consolidation this material, being harder than the surrounding lake beds, has been left standing out in prominent pinnacles. No trace of lake beds was found in this wadi wash, and it therefore seems probable that it was laid down by intermittent streams flowing into the Neolithic lake as its level gradually fell. Had it been cut while the first lake was drying up, deposits of the second period should have been found in it as the level rose again.

HIGH LEVEL GRAVELS.

The early history of the Fayum basin from the close of the Oligocene is still obscure. High level terraces of coarse material have been noted at various points around the basin, chiefly on the eastern and northern sides, and have been assigned by Beadnell and Blanckenhorn to a possible Pliocene age. Fossils of that period have not been found in the Fayum, though Schweinfurth discovered them on the Nile Valley side of the Fayum ridge at 197 feet above sea level.

There are, however, lower gravels, in places full of *Corbicula*, which probably point to an earlier stage in the Pleistocene history of the area than that denoted by the 74 ft. lake.

These gravels were only discovered at the end of the season's work. They lie at levels between 97 and 112 feet O.D. and are therefore well above the maximum of the old lake. Time did not allow of the relationship of the two being determined, and nothing more can be said of them until further work has been done. It may, however, be noted that the gravel lenticle found in the upper part of "L" wadi is composed of material very similar to that of the high level deposits, and the latter may therefore be regarded tentatively as the oldest freshwater deposits of the Fayum basin.

SUMMARY AND CONCLUSIONS.

It is, however, quite obvious that the Pleistocene history of the depression is a complicated story of varying lake levels. At least four of these have been determined :—

(1) The 97–112 ft. level, not previously recorded, and probably the oldest.

(2) The 72 ft. old lake level, formerly considered to be the ancestor

Faunal List.	Species not previously recorded from Fayum lake beds.	High level Gravels	Old lake, 74 ft.	Neolithic lake, 57 ft.	Recent lake, 12 ft.	Birket-el-Qerun.	Distribution in other parts.
**Ancylus ? isseli* Bourguignat	×	—	—	×[2]	—	—	Lower Egypt.
**Ampullaria ovata* Olivier	×	—	×[1]	×	—	—	Nile, L. Tanganika, Siwah, W. Africa. † *Sub-fossil.*
Bythinia badiella (Parreyss) Küster	×	—	×	×	—	—	Syria, Alexandria (coll. Dautzenberg).
**B. goryi* Bourguignat	—	—	×[3]	×	—	—	Nile, L. Mareotis, Greece, and Rome (Jick.).
B. senaariensis Parreyss	×	—	—	×	×[1]	—	Nile, Anseba.
B. tilhoi Germain	×	—	×[3]	×	—	—	Lake Albert, Lake Chad.
Cleopatra bulimoides Olivier	—	×	×[1]	×	×	×	Nile, Abyssinia, L. Chad. † *Sub-fossil.*
C. pirothi Jickeli	—	—	—	×[1]	×	—	Anseba, L. Albert, Brit. E. Africa. † *Sub-fossil.*
C. pirothi var. *multicarinata*	—	—	—	×	—	—	
**Isidora truncata* (Fér.) Audouin	—	—	×	×	×	×	Nile, Abyssinia, Algeria, Tunis, S. and W. Africa, S. Europe. † *Sub-fossil.*
**Lanistes carinatus* Oliv.	—	—	×[1]	×	—	×	Nile, Victoria Nyanza, Italian Somaliland. † *Sub-fossil.*
L. carinatus var. *perfecta* Pall.	×	—	—	×	—	—	Nile; Italian Somaliland.
**Limnaea cailliaudi* Bgt.	×	—	×	×	—	—	Blue Nile, Upper Nile, and whole of Africa.
L. natalensis Krauss	—	×	×	×[1]	—	—	Nile, Abyssinia, L. Nyassa. Tropical and S. E. Africa.
**L. truncatula* Müller	×	×	—	—	—	—	N. Africa, Abyssinia, Sudan, S. Africa, Europe.
**Melania tuberculata* Müll.	—	×	×	×	×	×	Whole Africa, Asia, Europe, etc. † *Sub-fossil.*

Paludestrina peraudieri Bgt.	×	—	×[2]	—	×	×	Algeria, Syria. ? *Sub-fossil.*
Planorbis bridouxianus Bgt.	×	—	×	×	—	—	Abyssinia, L. Tanganika, L. Albert, L. Chad.
P. alexandrinus Ehrenberg	—	—	×	×[1]	—	—	Lower Egypt. † *Sub-fossil.*
P. ehrenbergi Beck.	—	—	×	×	×	×	Nile. † *Sub-fossil.*
**P. mareoticus* (Letourneux) Innes	×	—	×	×	×	—	Lower Egypt.
**P. marginatus* Drap.	—	×	—	—	—	×	N. Africa, Syria, Europe, etc.
Segmentina angusta Jickeli	×	—	×[2]	×	—	—	L. Mariut, White Nile, Abyssinia.
**Theodoxus niloticus* Reeve	—	—	×	×[1]	×	×	Nile.
**Valvata nilotica* Jickeli	—	×	×	×	×	×	Nile.
**Viviparus unicolor* Olivier	—	—	×[1]	×	—	×	Nile, Abyssinia, Victoria Nyanza, Senegal, Tropical and South Africa.
Aetheria elliptica Lamarck	×	—	—	×	—	—	Tropical Africa.
Cardium edule var. *clodiensis* Renier	—	—	—	—	—	×	Shott Ovargla, S. Algeria.
**Chambardia locardi* Bgt.	×	—	—	×	—	—	Sub-fossil at E. end of Wadi Tumilat.
Corbicula africana Krauss	×	—	×	×[1]	×	—	Whole of Africa.
C. artini Pallary	×	×	—	—	—	—	Characteristic of Upper Nile; rare at Alexandria.
C. consobrina Cailliaud	—	×	—	×	—	×	Nile, Abyssinia.
C. innesi Bourguignat	×	×	—	—	—	—	
Mutela nilotica (Fér.) Sowerby	—	—	—	×	—	—	Blue Nile to Delta, L. Albert.
**Nodularia gaillardoti* Bgt.	×	—	—	×	—	—	Nile.
**N. teretiuscula* Phil.	×	—	×	×[1]	—	—	Nile.
**Pisidium ? casertanum* Poli	×	—	—	×	—	—	L. Egypt. Europe; N. Africa; Sudan.
Scrobicularia cottardi Payr.	—	—	—	—	—	×	Mediterranean.
Spatha cailliaudi Martens	—	× ?[3]	—	×	—	—	Nile.
**Sphaerium pharaonum* Bgt.	×	—	—	×	—	—	L. Egypt.
Unio aegypticus (Fér.) Caill.	—	—	—	×[2]	—	—	Nile.
**U. canopicus* Bourguignat	×	—	—	×	—	—	Nile.
**U. niloticus* Caill.	×	—	—	×	—	—	Nile.

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[1] Characteristic.
[2] Position doubtful.
[3] Identification uncertain.

* Figured by Pallary, op. cit. and supplement, 1924.

† *Sub-fossil* around Lake Mariut, together with *Cardium* and other marine forms (Blanckenhorn, op. cit., 1901, p. 466).

of Lake Moeris, but now shown to have been a far older sheet of water.

(3) The 57 ft. Neolithic lake level, which came into existence after the old lake deposits had been hardened and eroded, and around which the Neolithic Fayum flint-using people lived after it had retreated from its maximum level.

(4) The 12 ft. level, most recent, probably in existence in historic times.

The problems of the relationship between all these, of their age and of the length of their duration, as well as the broader questions of their possible connexion with climatic changes in other parts of the world, must be left until the whole basin has been further surveyed.

I should like to acknowledge my very great indebtedness firstly to my friend and former tutor Dr. Gertrude Elles, F.G.S., for constant help and advice, not only in the preparation of this paper, but at all times, and secondly to Miss Caton-Thompson for valuable suggestions both in the field and at home. I have to thank Mr. G. Robson, of the British Museum, for permission to use the library and the specimens in the conchological department. I am particularly grateful to Major Connolly for the identification of the freshwater fauna and for his general interest in the paper, and to Mr. Tomlin for naming the brackish water types and helping with the other forms. Finally, I should like to express my thanks to Mr. E. Reeves of the Royal Geographical Society for his ready help in all matters pertaining to the making of the maps, which are the basis of the field work.

SYNONYMS.

Isidora truncata = *I. contorta* and *I. brocchi*.
Lanistes carinatus = *L. bolteni* Chemn.
Limnaea cailliaudi = *L. africana* Rupp.
Paludestrina peraudieri = ? *Hydrobia stagnalis*.
P. alexandrinus = {*Segmentina alexandrina*. / *Planorbula*.
P. ehrenbergi = *P. cornu* Ehr.
Theodoxus niloticus = *Neitina nilotica*.
Nodularia teretiuscula = *Unio teretiusculus*.

According to the latest authority :—

Bythinia = *Bulimus*.
Isidora = *Bulinus*.
Melania = *Melanoides*.

BIBLIOGRAPHY.

(1) 1926, Gardner, *Brit. Ass. Oxford*, p. 393.

(2) 1926, Gardner and Caton-Thompson, "The Recent Geology and Neolithic Industry of the Northern Fayum Desert," *Journ. Roy. Anthrop. Inst.*, vol. lvi, pp. 301–23.

(3) 1905, Beadnell, H. J. L., *Topography and Geology of the Fayum Province of Egypt*, Egypt Survey Dept., Cairo.

(4) Beadnell, op. cit., pp. 79, 81.

(5) Caton-Thompson, op. cit., p. 310, pl. xxxiv.

(6) 1896, Morgan, J. de, *Recherches sur les Origines de l'Égypte*, p. 73.

(7) 1903, Review of Gov. Geologist's Report, W. Australia, Geol. Mag., Dec. IV, Vol. X, p. 568.

(8) 1909, Pallary, P., "Catalog. d. l. Faune Malacologique d'Égypte," *Mem. l'Instit. Egypt*, vol. vi, i, p. 84.

(9) 1890, Bourguignat, J. R., *Bull. Malacol. Soc. d. France*, vol. vii, p. 304.

(10) 1908, Smith, E. A., "Mollusca of Birket-el-Qurun, Egypt," *Proc. Malac. Soc.*, vol. viii, pt. i, March, p. 10.

(11) Smith, op. cit.

1901, Blanckenhorn, M., *Das Pliocän & Quartärzeitalter in Aegypten, Zeitschr. d. Deutsch. geol. Ges.*, Bd. liii, Heft 3, p. 463.

1921, Blanckenhorn, M., *Aegypten. Handbuch d. Region. Geol.* Heidelberg, Bd. vii, p. 162.

(12) Smith, op. cit., Blanckenhorn, 1901.

(13) 1878, Tournouër, M., *Ass. Fran. pour l'advanc. des sciences*, Paris.

(14) 1886, Schweinfurth, G., "Reise in das Depressionsgebiet im Umkreise des Fayums in Jan., 1886," *Zeitschr. d. Ges. f. Erdk.*, Berlin, p. 39.

"Le Moeris."

Under this title M. Georges Hug has recently[1] brought out a paper on the Fayum lake levels, basing his conclusions on evidence obtained from the south side only.

His article was brought to our notice after our paper was finished, but since his observations are of importance and supplement the evidence gained on the northern side, a brief account of them and his conclusions are given below.

In an appendix to his own paper he has similarly summarized the geological section of the paper in the *Anthropological Journal*, and while agreeing with the facts, criticizes our conclusions severely. These criticisms will also be dealt with.

Briefly M. Hug believes that :—

(1) In the last interglacial period—Riss-Würm—there was a high level lake filling the Fayum and Ryan depressions. This was in connexion with the Nile, whose flood periods were as at present. The deposits consisted of alternating sands and clays, representing high and low water respectively.

(2) The lake rose still higher in the last glacial period—Würmian. The glaciation of Central Africa affected the climate of the Fayum, which became hotter and wetter. The Nile at this period almost filled its valley, the level remaining the same at all seasons; the material carried into the Fayum—chiefly mud—was laid down at the entrance as a submarine delta. This lake is called Pre-Moeris and prehistoric man lived around its shores, which are represented by high level gravels between 35–40 metres (115–131 feet O.D.) in the Hawara-Lahun Channel.

(3) As the climate became drier after the glacial period the lake level sank, the waters in the Ryan were cut off from those in the

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[1] *Bull. Soc. Roy. de Geog. d'Egypte*, Tome xv, May, 1927, pp. 1–44; Appendix, pp. 45–50.

Fayum and gradually dried up. As the level in the Fayum sank the deltaic fan appeared above the surface; the waters of the Bahr Yusuf no longer filled the channel, but eroded the pre-existing deposits. At 20 metres (65·5 feet) the sinking of the level slowed down and for a time inflow equalled evaporation, giving a shore line in front of the bordering cliff. This lake was the precursor of Moeris.

(4) As subsidence continued the lake shores passed through various stages of emergence, giving rise, among other features, to the Edwa-Seila bank.

(5) The mature stage of emergence is represented by Lake Moeris, as Herodotus saw it, with its shore line between 17 and 18 metres (56–59 feet). It was not used as a reservoir in his day, and the historic lake never rose to the old supposed level of 22 metres (72 feet).

(6) This level was not of long duration, the waters fell to between 15–16 metres (49–52 feet) at low Nile, rising to 18 metres (59 feet) at high Nile. The fall was then more rapid, and soon after the arrival of the Macedonians the lake was below sea level.

From the above summary it will be seen that there is considerable agreement between M. Hug and ourselves. We differ mainly on the following points :—

(1) M. Hug states that our 23 metre (74 ft.) lake did not (*a*) exist, (*b*) disappear entirely or completely, and that the 18 metre (our Neolithic lake) is the only one in accordance with the truth and that that is historic.

We would reply that M. Hug has himself shown a 20 metre stage, which might well correspond with our old lake, and we would charge him with paying far too little attention both to the stratigraphical relation of the beds and to their invertebrate fauna. The latter he has almost entirely ignored, a true view can be obtained only by taking *all* factors into consideration.

(2) M. Hug, owing doubtless to a hasty reading of our paper, states that we have shown only two lakes, whereas there were " a multitude ". He implies that we do not admit a high level lake, but on p. 306 we say that the Fayum was filled to *at least* 22 metres. The geological section was a much compressed abstract of a short introduction to an archaeological paper. It embodied the results of *one* season's work, and could only deal with the new geological evidence relevant to the archaeological questions under discussion.

If M. Hug believes in a " multitude " of lakes it is perplexing to be able to identify in his paper a solitary one only of varying levels. We would remind him also of the history of such classic lakes as Bonneville and Lahontan, situated in nearly the same latitude as the Fayum.

(3) On p. 48 M. Hug accuses us of taking no account of the concordance of the chronology between the quaternary deposits and the prehistoric stations. Here again he mistakes the limited scope and intentions of the papers; in the field such correlation

s ever present to the mind of the prehistorian, it is indeed the main purpose of his work. For the first time in the history of the archaeological exploration in the Fayum we effected a detailed inquiry nto the geological associations of a specific flint industry, whose period was unknown. That industry is now shown to be long post Palaeolithic, and is definitely and consistently related to the 18 metre lake. We are aware that M. de Morgan carried out work there ostensibly on geological lines, but since his levels—the fundamental basis of all such inquiry—are extremely inaccurate the contribution is valueless.

In regard to the Palaeolithic, if M. Hug will consult the last paragraph on p. 313 of our report he will see that freshwater gravels at 255–60 feet over lake (33–34·5 metres O.D.) are noted, as well as their Palaeolithic associations. If we do not feel justified at this moment in interpreting this fact with the far-reaching liberality of M. Hug's conclusions based on "eoliths and Upper Palaeolithic nodules"[1] in brick earth at El Alam (p. 20), it is because we do not wish to add to a "multitude" of premature conclusions based on insufficient evidence. The equation 260 ft. gravels + Mousterian flints + *Corbicula* = Würm = Monasterian terrace (10–15 metres) is easily written, but has yet to be proved, and consequently it had no place in our paper.

(4) M. Hug suggests that we have mistaken the Tertiary silicified wood for that of more recent origin. This, however, is impossible, the material on the mounds is *not* silicified, but composed largely of carbonate of lime. We are quite prepared to admit that further work may prove our "sand mounds" to be features of the emerging shore line, similar to that shown in M. Hug's excellent section on p. 32; but this would not invalidate our argument since both are closely connected with the shore line. Further, this same section agrees in a remarkable manner with those measured by us on the north side and seems to strengthen and confirm our conclusions completely, except that for the level marked "Moeris" we would substitute "Neolithic".

Apart from the valuable data collected by M. Hug on the south side, what strikes one most on reading his paper is the weight of theory which is supported by relatively few facts. For the changes of climate the only evidence given is that of the varying succession of the beds seen in certain brick pits. Conditions of deposition are nfluenced by a great many factors; of these change of climate is but one, and no attempt is made to show that the other factors were not responsible for the changes observed.

A correlation is drawn between the glaciation of Central Africa and that of Europe, but no proof of this is given and one would like to know the sources from which this information was obtained. The supposed hotter and wetter climate of the Fayum in Würmian times comes as a surprise. There is general agreement that the climatic belts move southward in the glacial periods ; this would bring the Fayum into a wetter belt certainly, but a cooler, not a hotter one.

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[1] "Les silex, que nous avons rapportés, sont soit des éolithes, soit des rognon appartenant au Paléolithique supérieur."

Again, it is definitely stated that the Ryan was filled with water. The divide between the Ryan and Fayum basins now averages 35 metres (Beadnell, p. 17), but it does not necessarily follow that it was at the same height in the inter-glacial and glacial periods, and unless actual lake deposits have been found by M. Hug in the Ryan, his conclusions cannot be accepted on the evidence of level alone.

Similarly his positive statement that the 18 metre level is that of the historic lake Moeris, seems to rest on insufficient evidence. A consideration of the Neolithic levels on the north side of the lake would seem to show that the 18 metre lake had already fallen from its maximum before the establishment of the main Neolithic sites (see folding map, Pl. XI).

The Limestone of the Kinta Valley, Federated Malay States.

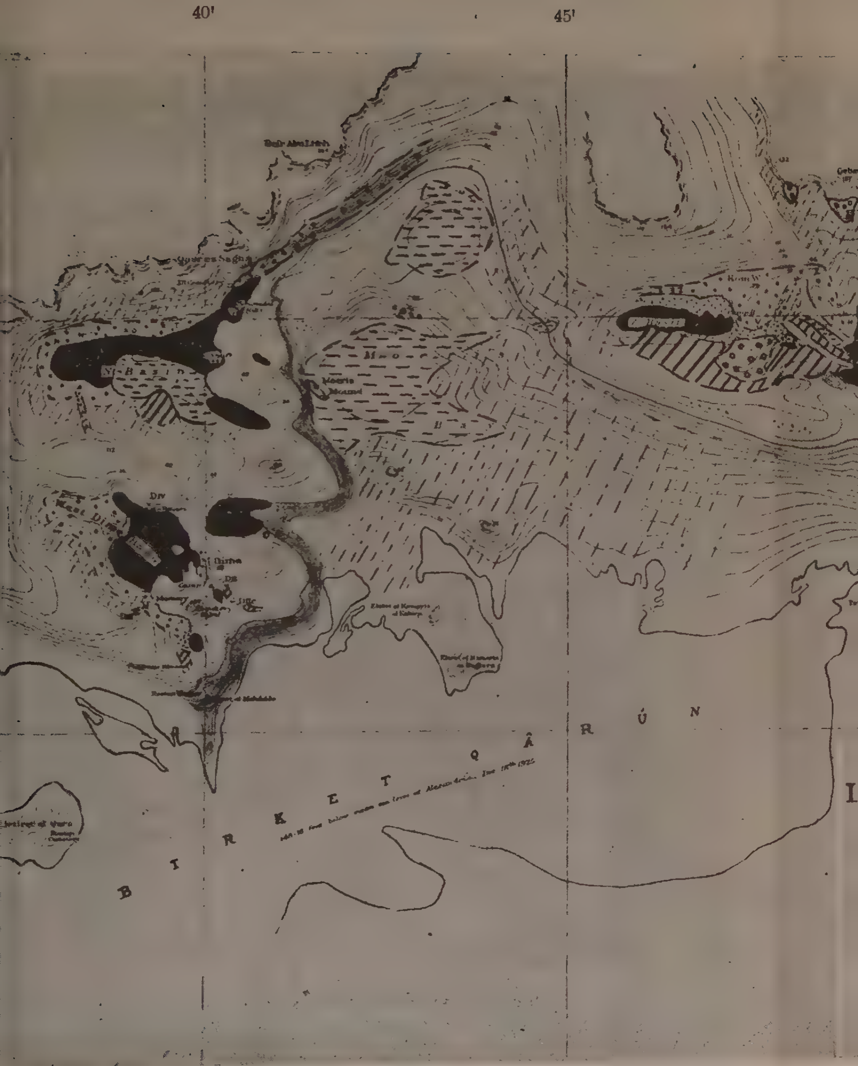
By R. H. Rastall.

I. Introduction.
II. The Age of the Limestone.
III. The Supposed Existence of two Limestones.
IV. The Relation of the "Schist Series" to the Limestone.
V. The Western Boundary of the Limestone.
VI. The Thickness of the Limestone.
VII. The Problem of the Limestone Hills.
VIII. Summary and Conclusion.

I. Introduction.

THE following paper is not intended as a serious contribution to the stratigraphy of the limestone series of the Malay Peninsula. The title is rather to be regarded as a convenient peg on which to hang certain rather miscellaneous reflections that suggested themselves during a recent visit to that country.

I was requested by the Government of the Federated Malay States to go to Malaya in December, 1926, and to spend three months there in order to report on several disputed points in the geology of the Kinta Valley, in the State of Perak, the most important tin-mining area of the British Empire. I examined that district very thoroughly, travelling several thousand miles by motor over its excellent roads, also making flying visits to other localities whose geology had a bearing on the points at issue, even as far south as Singapore, where by kind permission of the Asiatic Petroleum Company I was enabled to visit the excellent exposures of the Triassic sediments on Pulau Bukum, their great tank station outside


40'
45'
Deir Abu Lifah
Qasr es Sagha
Basin
Dime
Moeris Mound
B I R K E T Q Â R Ú N
Kom W

Keppel Harbour. Besides two formal reports to the Government, by kind permission of the Honourable the Chief Secretary the purely scientific results of my work have already been published in summary in the *Mining Magazine*.[1] In the present paper, some of the points there briefly touched on are dealt with in a little more detail, but

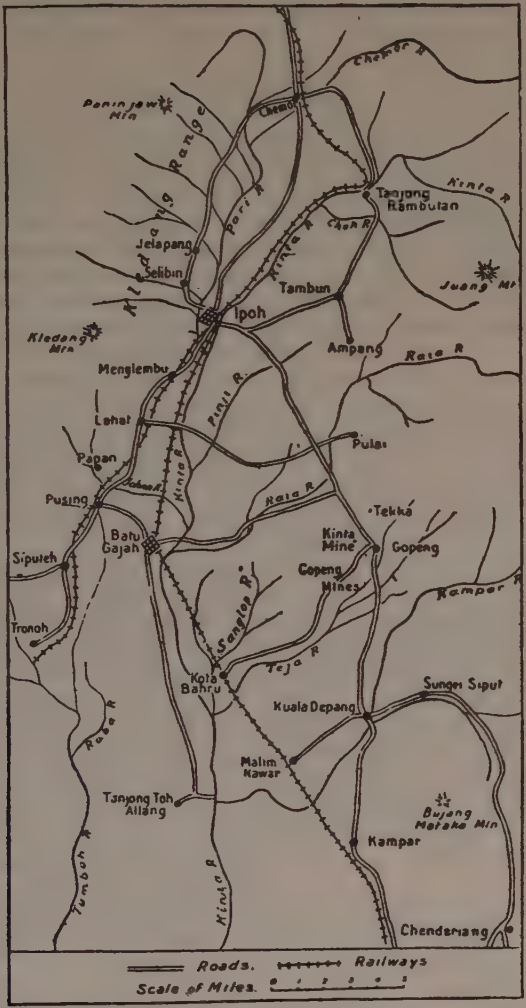


FIG. 1.—Sketch-map of the Kinta District. Reproduced from the *Mining Magazine*, by permission of the Editor.

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[1] Rastall, "The Geology of the Kinta Valley," *Mining Magazine*, vol. xxxvi, 1927, pp. 329–38.

only those which are in some way or other connected with the limestone formation. Even this limitation leaves a pretty large field, since it raises problems of a stratigraphical, petrological, structural, and physiographical character, as will duly appear in the sequel.

II. The Age of the Limestone.

This section contains no original work based on my own observations, but is purely a compilation from published sources.

The Raub Series, of which the Kinta limestones form part, covers a large area in the Malay Peninsula, as may be seen from an inspection of the admirable map on the scale of 6 miles to the inch recently published by the F.M.S. Government. However, it is not all limestone: east of the Main Range in Pahang (e.g. at Raub itself), and in the south, in Negri Sembilan and Malacca, a shaly facies is prominent. The base of the limestone is seen only in the extreme north-west in the Langkawi Islands, where it rests on a series of quartzitic beds, believed to be of Lower Carboniferous age. The thickness of the limestone is here computed by Mr. Scrivenor at about 5,000 feet. In the Kinta Valley there is no means of estimating the original thickness, since it is always in contact with intrusive granite below, but for reasons which will appear later, there must be several thousand feet of it.

None of the existing palaeontological evidence for the age of the limestone has been obtained in the Kinta Valley, where in point of fact the conditions are very unfavourable for the discovery of fossils. Most of the tin mines in which limestone is exposed are naturally near the granite contacts, where the metamorphism is very intense, the rock being usually converted to a coarsely crystalline marble. In the middle of the valley, exposures are not very numerous, and the rock is often fairly crystalline, as if the granite is at no great depth. In the limestone hills, on the other hand, fossils would also be difficult to find, for various reasons. For one thing the limestone is often strongly folded and crushed by shearing. Again, vegetation is very luxuriant, even on almost vertical faces, several hundred feet high: the rocks are also for the most part difficult of access, but the greatest obstacle of all is the tremendous development of secondary stalactitic calcite, which often makes it impossible to determine even dip and strike over large areas.

Mr. Scrivenor has described crinoid ossicles drawn out into streaks in limestone pinnacles in an old mine at Changkat Pari, north-west of Ipoh, and in a visit of a few minutes only to a road-metal quarry at Gunong Kantang, 2 miles north of Chemor, by the side of the main road to Kuala Kangsar, I found some large and well-preserved crinoid ossicles in a rather fine-grained black limestone. A thorough search here by a Carboniferous specialist would probably yield a fauna.

Considering the available palaeontological evidence as a whole, the results are rather conflicting. From various localities fossils have been described and assigned to ages ranging from Viséan to Permian.[1] The strata below the limestone in the Langkawis, which I have not seen, may be Lower Carboniferous. It will sufficiently serve the present purpose if the limestone of the Kinta Valley is designated as Permo-Carboniferous, using this term in a very broad sense. It is to be noted that this is a facies differing very greatly from the more normal Gondwana type of India and the southern hemisphere. For the benefit of readers unacquainted with the country, it may perhaps be added that much of it, where not strongly metamorphosed, is very like the Carboniferous Limestone of the British Isles in its general appearance, and there are resemblances to the scenery of parts of Derbyshire, for example, though on a bigger scale. There is no typical Karst topography. Probably the rainfall (anything from 90 inches upwards) is too high for the proper development of this.

III. THE SUPPOSED EXISTENCE OF TWO LIMESTONES.

In an important paper which has attracted much attention, Mr. W. E. Cameron,[2] lately Economic Geologist to the F.M.S. Government, has put forward his view that the limestones of the Kinta Valley include two distinct formations, separated by a long interval of time, and with some important tin-bearing deposits between them, constituting his "Deep Leads". Mr. Cameron endeavours to show that his "older limestone" is of earlier date than an "older sheared granite" by which it was invaded and metamorphosed, and that it was likewise sheared and brecciated by the same set of earth-movements as gave rise to the shearing in the granite. This period of disturbance was followed by the formation of the "deep leads", a set of tin-bearing detrital sediments, and this again by the deposition of the newer limestone. In a general way the older limestone is said to form the greater part of the floor of the Kinta Valley, although a considerable area on the western side is mapped as newer limestone, while the last-named formation constitutes the limestone hills which are so conspicuous a feature of the local topography.

The preceding paragraph summarizes very briefly, but I believe fairly, a theory which will have to be considered here in some detail, since as a result of personal observation I believe its main features to be wholly erroneous. Furthermore, Mr. Cameron states that the so-called "schist-series" is older than any of the limestone. This statement is certainly untrue, as will be shown in detail in a later section: this question will be here disregarded for the present and attention will be confined to the limestone problem.

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[1] Scrivenor, "The Palaeontology of British Malaya," *Journ. Malayan Branch Royal Asiatic Society*, vol. iv, 1926, pp. 178–83.

[2] Cameron, "The Deep Leads of Kinta Valley," *Mining Magazine*, vol. xxxi, 1924, pp. 276–85.

In addition to the publication above cited, during my stay at Batu Gajah I had the advantage of examining Mr. Cameron's manuscript maps of the Kinta Valley, so that there is no doubt as to his own interpretation of the evidence, or as to what he meant precisely by the descriptions given in his paper, which is not always quite clear from the text.

In the first place, in my official reports to the Government and in the paper in the *Mining Magazine* above cited, I have given at some length my reasons for believing that all the granites of the Kinta Valley are of the same general age, namely, late Mesozoic, and subsequent to the deposition of the whole of the limestone of that area. There is no evidence in Kinta for the existence of Mr. Cameron's "older sheared granite".

Secondly, in the same way, I have stated my deliberate and carefully considered conclusion that there are no "deep leads" in the Kinta Valley. The evidence on which these two statements are based is fully set forth in the paper in the *Mining Magazine*, and need not be repeated here.

It is obvious that on Mr. Cameron's theory there should be a violent unconformity between the two limestones, and that the "deep leads" should come between them. In his original manuscript map and in the portion of it reproduced in the *Mining Magazine* for November, 1924, Mr. Cameron shows the two limestones in contact over scores of miles of boundary, but never anything between them. This is specially noticeable in the south-eastern portion of the MS. map in the country around Gopeng, not reproduced in the paper cited, where there are numerous small limestone hills scattered about and rising above the plain, but the same state of affairs also prevails on the western side, around Menglembu, Lahat, and Pengkalen, where a considerable area, extending also past Papan and Pusing towards Tronoh is mapped as "Upper Limestone". From the map in the *Mining Magazine*, taking its accompanying legend as indicating the true succession, it is impossible to construct an intelligible section from Lahat Mine to Pengkalen, or east and west through Menglembu. By kind permission of the Editor of the *Mining Magazine*, this map is here reproduced as Fig. 2.

Further, I am unable to imagine, and Mr. Cameron nowhere explains, what criterion he used in separating this western area of "upper limestone" from the rest of the limestone forming the floor of the valley. As will appear later, there are no limestone hills on this western side, and petrographically the limestone is identical with that forming the floor on the eastern side, down to minute details. This is specially noticeable with regard to the black and white banding, which forms so prominent a characteristic of the limestone on both sides of the valley, and is extremely unlikely to be faithfully reproduced in formations of two totally different ages.

But still more important is the fact that in many mines on the east side of the valley, the low-level "pinnacle" limestone of the floor can be followed up in continuous sections without any break into the limestone of the hills. One of the best examples now visible

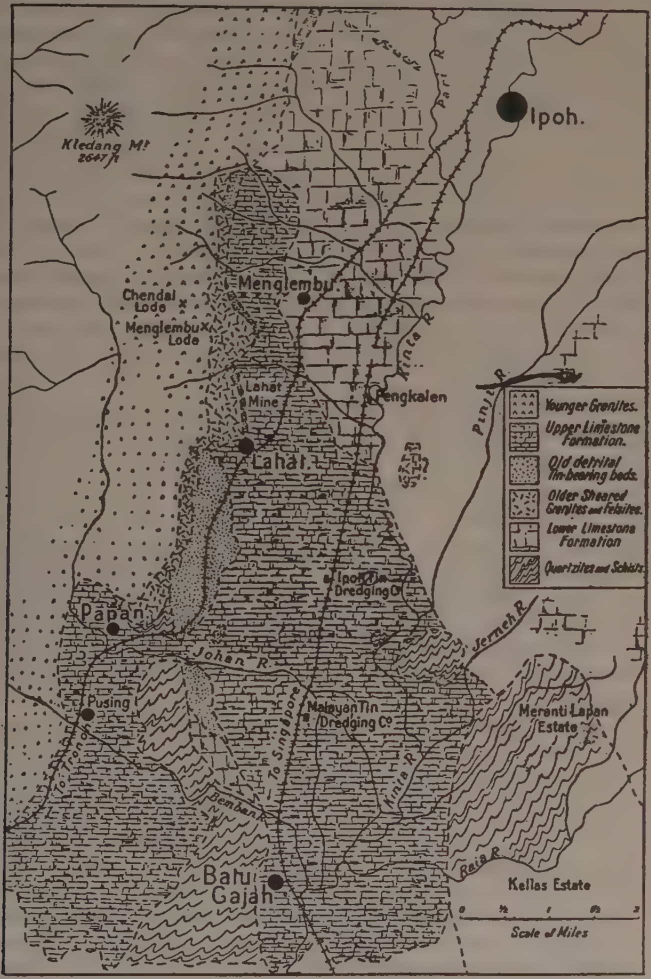

FIG. 2.—Mr. Cameron's geological map of part of the Kinta Valley. Reproduced from the *Mining Magazine*, by permission of the Editor.

s the south section of Krámat Pulai mine, where the relations are pecially clear. Another case, in a Chinese mine near Ampang, has been figured in the *Mining Magazine.*

At this point it may be well to explain exactly what is meant by the expression "pinnacle limestone" used in the preceding paragraph. One of the most remarkable features of Malayan geology is the extraordinarily rough surface of limestone on which the later formations rest. This must really be seen to be believed, but some photographs published in the various memoirs issued by the Geological Department of the Federated Malay States give a very good idea of it. The upper surface of the limestone, though on the average more or less flat when viewed on broad lines, is in detail carved into a series of pinnacles and cups of the most fantastic forms, and this statement is true, so far as my observations go, of the whole of the floor of the valley. The structures bear some resemblance to the "grikes" of Ingleborough, for example, but in a very exaggerated form, and in very many places there are great holes of a cup-like form, up to scores or even hundreds of yards across, filled with peat and tin-bearing alluvium, or sometimes largely occupied by masses of the collapsed overlying strata or various types of boulder-clays. Even in these great hollows there may be isolated pinnacles of limestone of the strangest forms, sometimes as much as 50 feet high.

When considered in detail, it is perfectly clear that these extraordinary forms are due to solution of the limestone. On this point there can be no doubt, but the principal problem is whether this solution was at the surface or subterranean, below the overlying deposits. My own opinion is that it was very largely subterranean, and that it is still actively going on. Subsidences sometimes occur, as for example along the main railway line near Pengkalen, between Ipoh and Batu Gajah. The line here has to be constantly patrolled. I believe that some of the most difficult problems of Malayan geology, not here touched upon, can be solved by collapse of overlying deposits into hollows produced by underground solution of the limestone.

It was stated above that the generalized surface of the limestone of the valley is flat. This can be seen in numberless open lombongs all over the district; as specially good examples I would mention the old mine of Siputeh, which has been often illustrated; Changkat Pari, north-west of Ipoh; the December mine, Kacha; the Thoon Hoe mine, near Lahat; and a recently opened Chinese mine below the south end of Gunong Laiang Laiang, near Tanjong Rambutan. But it must not be supposed that this flat surface represents the original upper surface of the limestone. It is obviously a plane of denudation. In this regard the last-named example is specially instructive. The limestone here is strongly banded, so that the dip and strike are conspicuous, and in all the pinnacles the steep westerly dip is very clearly shown. Fig. 3 is a reproduction of a diagrammatic sketch made on the spot. The same relations hold all over the district, and the bedding of the limestone is very rarely horizontal, while in many places it is violently contorted.

It should perhaps be mentioned that solution effects extend upwards to a considerable height into the limestone hills; most of them are strongly undercut, with caves, at the base, and water-levels obviously due to solution run round them at various heights. It is impossible to avoid the conclusion that much of this is due to moving water, probably marine, at no very distant date, but this cannot account for the shapes assumed by limestone pinnacles with a more or less conformable covering of the schist series, and caps of ironstone, such as are constantly being uncovered in the mines. These pinnacles must undoubtedly have assumed their present forms underground.

Thus it appears that the present general flat surface of the valley limestone can in no way be regarded as the original upper limit of a "lower" limestone. And in point of fact, the present surface of Mr. Cameron's "upper limestone" area on the west side of the valley is exactly similar in every way to the surface of his "lower limestone" in the middle and on the east side of the valley.

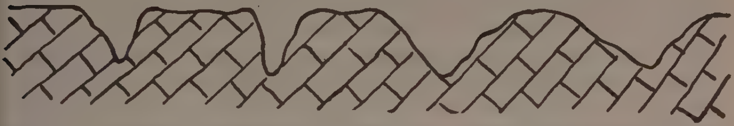

Fig. 3.—Limestone pinnacles in a mine near Tanjong Rambutan, showing relation of dip to the flat upper surface (diagrammatic).

From the evidence here detailed it is concluded that there is no foundation for the supposed division of the limestones of the Kinta Valley into two unconformable formations and the whole of it is here assigned to one single age, namely Upper Carboniferous, or Permo-Carboniferous.

IV. The Relation of the "Schist Series" to the Limestone.

In this paper the term "schist series" is employed, for the sake of brevity and in conformity with local usage, to indicate the quartzite-shale-phyllite series which occupies so large an area in Malaya, irrespective of its degree of metamorphism at the particular locality dealt with. In some places it consists of almost unaltered sediments with fossils; more commonly, however, it is unfossiliferous; locally it has undergone all degrees of metamorphism, especially of course, near the granite ranges; very commonly also, even where strongly crystalline and metamorphic, the whole has been converted by tropical weathering to soft and tenacious clays, sometimes still showing clearly the original structures, sometimes wholly structureless, but usually containing "core-boulders" of the original unaltered rock. Naturally, all gradations exist between these different types. A very important point is that near the granites these rocks carry tin and have undoubtedly yielded much ore to the alluvial and other deposits of the Kinta Valley.

In the paper by Mr. Cameron before cited, the following sentence occurs[1]: "Detailed mapping of selected areas and observation of scattered sections show conclusively that the quartzites and schists form a distinct series on which the sheared limestones lie unconformably, and that they are older than these limestones." There is no possibility of misunderstanding the meaning of this categorical statement and the only answer to it is an unqualified contradiction. Clear and unmistakable field evidence shows nothing of the sort, but the exact opposite. The schist series is newer than and rests on, the limestones of the Kinta Valley.

It is obvious that so sweeping a statement requires abundant justification, but such is fully forthcoming from my own observations.

Before setting these observations out in detail, however, I would like to mention that a series of bores put down by the officers of the Mines Department at a spot chosen by Mr. Cameron himself, near the sixty-sixth milestone on the main road from Ipoh to Batu Gajah, have settled the question once for all. In the absence of express permission I am unable to publish the details of these bores, but the results are quite conclusive; schist was found above limestone.

My own observations bearing on this point extend to a number of mines all over the district, from Tanjong Tualang in the south-west to Tanjong Rambutan in the north-east, a total distance of about 25 miles. In many places I saw schists, in various stages of freshness and decay, clearly resting on limestone, sometimes apparently with complete conformity, and never schist below limestone. In one locality only, the Yau Yok Choo mine (Lot 11589, nearly due south of Gunong Panjang), did I see even a bed of shale interstratified with the limestone; this mine is exactly on the line of one of the great folds in the limestone, hereafter to be described, and it is clear that the shale band forms an integral part of the continuous limestone series, having the same dip and strike, and being strongly folded with the limestone, which is seen both above and below it. This shale band differs entirely in character from the decomposed schist, lying above the limestone in other parts of the same mine and also let down into cups and hollows between the pinnacles in the usual way.

Here follow brief descriptions of half-a-dozen localities where schist can now be seen resting on limestone. I may say that I possess photographs of nearly all of these, taken in my presence by Mr. Scrivenor or Mr. Willbourn, but on the ground of expense it is quite impossible to reproduce them here.

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[1] Cameron, loc. cit., p. 278.

(1) *Chinese Toh Allang Tin, Ltd., Tanjong Tualang.*[1]

The south end of the No. 1 mine shows black schists strongly folded with a conspicuous anticline 2 or 3 yards wide, much riddled by veins from the granite, and brecciated "a perfectly clear and excellent exposure of black schist on limestone".[2]

(2) *Phin Soon Mine, Tanjong Tualang.*

This mine shows many extremely interesting features, which cannot be described here in detail, including a curious mushroom-shaped mass of aplite intruded into decomposed schist. The south end of the pit shows grey clay with cores of more or less unaltered tourmaline-schist, mixed up with alluvium, the whole being disturbed by collapse over limestone. The line of demarcation of the schist and alluvium is marked by a line of pebbles, which in places is vertical owing to sinking into a limestone cup. Fig. 4 shows, somewhat diagrammatically, the relations of schist and alluvium to the limestone as seen on 7th February, 1927. Very shortly before I left Malaya, Dr. Ingham visited the same section, and he informed me that much of the mushroom and of the cup had been worked away, though he could still make out the pebble bed. It is quite clear that the grey clay shown in Fig. 4 is decomposed tourmaline-schist and "the same banded and contorted brownish schist occurs in place resting on a limestone pinnacle near the bottom of the mine".

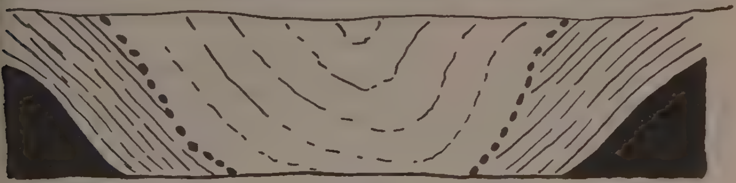

FIG. 4.—Diagrammatic sketch showing relations of limestone, grey clay (altered schist) and alluvium in the Phin Soon Mine, Tanjong Tualang.

(3) *Gedong Batu, near Batu Gajah.*

In this little known locality are several Chinese mines showing most interesting features, especially with regard to the relation of the tourmaline-corundum rocks to the schist series. This question s, however, now being investigated by the Geological Department nd will not be discussed here, as fresh evidence seems likely to be orthcoming as mining advances. The following are two extracts from my notebook: "the second mine visited shows an admirably clear section of black shale and quartzite resting on a limestone pinnacle. The bedding is clearly unconformable, and the schist series gives a strong impression of the settling down of a cap over the pinnacle as the limestone dissolved"; "fourth mine: good exposures of black shale on pinnacles."

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[1] Local spelling here varies somewhat. The official title of the company working the mine differs from the spelling adopted in the Government 1 inch map.

[2] In these sections sentences in inverted commas are verbatim transcripts rom my field notes, written on the spot.

(4) *Tak Hing Loong Kongsi.*

West of Pusing village (part of the old Pusing Bharu mine). A very clear section showing some remarkable overhanging limestone pinnacles, determined by tilted major joints. "Resting on the limestone is black schist, in parts altered to a structureless clay."

(5) *Rambutan, Ltd., Mine,* 1 *mile south of Tanjong Rambutan.*

Here I simply transcribe a whole page of my field note book, which speaks for itself.

"This mine shows some very clear sections of schist over limestone, the two series having apparently the same dip and strike; that is to say, there is evidence of complete conformity. The limestone just below the contact is dark, impure, and platy, while the shale is dark and soon passes into quartzite.

"In the floor of the pit is a good exposure showing the top of a pinnacle with highly inclined bedding overlain by schist: between them is an iron cap 2 or 3 inches thick, but no break can be seen in the succession. Both series strike N. 20° E., and the dip is very steep to the west; 70°–75°.

"This is a very satisfactory section, and there can here be no doubt that the schist is above the limestone."

From the facts of observation detailed above, it is scarcely necessary to elaborate further the thesis that the schists are above the limestone. Some points of interest concerning the relations of the two series in the limestone hill region on the east will be dealt with later (see p. 431). One point that arises now is, as to whether the two series are conformable or not. As to Gedong Batu it is stated above that "the bedding is clearly unconformable" and at the Rambutan, Ltd., mine "there is evidence of complete conformity". These two statements are not necessarily so contradictory as they seem, if we take into account the evidence already stated as to underground solution of the limestone. It is quite easy to imagine that in some places the limestone was dissolved away, while in others it was not, and the occurrence of one conformable section so clear as that at Rambutan suggests that this was the normal relation. But Gedong Batu and Rambutan are some 15 miles apart, and the relations might well be different at this distance. In any case the point is of no importance whatever in the general argument.

But the question can also be tackled from another and quite different point of view, namely that of general physiography. The flat, level floor of the Kinta Valley is very largely composed of alluvium overlying limestone, as is shown by the pinnacles of the last-named rock that project above the surface at innumerable points. In many places, however, its surface is diversified by low rolling hills, many of which consist of rocks of the schist series. Some of the rivers also flow on a limestone bottom between low hills of schist. An excellent example is afforded by the Sungei Johan, which runs over limestone between Redhills on the south, and Kacha on the north, by the side of the main road from Ipoh to Batu Gajah. Even an elementary acquaintance with physical geology ought to show that in such a case the hills are not likely to consist of the lower formation.

There is a further criterion that can be used as bearing on the question of the relative ages of the two formations, although this is not directly available in the Kinta Valley. In other parts of Malaya both of them contain determinable fossils, which show conclusively that the limestone is Carboniferous and Permo-Carboniferous, whereas the "schist series" is Triassic.[1] However, I have not myself seen this evidence in the field, and can only quote the work of others on this point. In several places I saw the Triassic rocks apparently unaffected by thermal metamorphism, but in these localities no fossils have yet been discovered. There seems to be no doubt as to the correctness of the correlation of these fossiliferous strata with the barren rocks of the Kinta Valley. On the west of the Kledang Range, towards Parit and the Blanja Ferry over the Perak River, the "schist series", here not metamorphosed, becomes much more quartzitic, and this type of sediment is notoriously unfavourable to the preservation of fossils, while between the Kledang Range and the Main Range, in the Kinta Valley itself, thermal metamorphism is almost everywhere very intense, tropical weathering has in most places led to more or less complete disintegration of the metamorphosed Triassic sediments, while the limestones are highly crystalline. It seems very unlikely that good fossils will ever be found in the schist series in Kinta, although as before stated there are possibilities in the limestones towards the north.

Since the relations of the limestone and the schist series on the eastern side of the valley, at the foot of the Main Range, have some bearing on the problem of the limestone hills, to be discussed later, it may be worth while to give a short account of some observations made by Mr. Willbourn and myself in that area. It must be clearly understood, however, that I am solely responsible for the interpretation here placed on these observations.

The first locality to be described is the east face of Gunong Terendum, a great limestone hill 1,500 feet high, about a mile north of Pulai. The road to it passes close to the old scheelite mine, now flooded, and awaiting better markets for its product. Between the small limestone hill of G. Macham Api and the great eastern cliff of G. Terendum, is a narrow strip of schist and some granite, while all to the east is granite. Following a very rough track northwards, we soon came to loose blocks of schist forming the slope at the foot of the cliff, and then scrambling up a steep slope to the very foot of the overhanging part, close to a wild goat trap, we found a schist-limestone contact following the line of the cliff and approximately vertical. The cliff here overhangs dangerously and rock-falls have been frequent.

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[1] Scrivenor, "The Palaeontology of British Malaya," *Journ. Malayan Branch Royal Asiatic Society*, vol. iv, 1926, pp. 173–84, with references.

As this is very difficult ground, at a later date four Malay collectors were sent out to cut a path along the contact: to give an idea of the thickness of the jungle, I may say that in a whole day the four of them only got about a mile, but when examined subsequently, this mile gave very interesting results. The most significant facts are:—

> the contact is nearly vertical, with slight variations on either side, leaving what may be described as "splashes" of schist on the face of the cliff;
>
> the foliation-planes of the schist are roughly parallel to the contact plane;
>
> the black banding in the limestone can be distinguished in the cliff as high as the eye can reach, and this banding also is parallel to the contact;
>
> in one or two places narrow veins of granite were found cutting both schist and limestone.

The diagrammatic sketches in Fig. 5, copied from my field note-book, show a front view and a section at right angles to it of the schist and limestone as seen at one point. This shows clearly the dangers inherent in a partial view of any exposure, and in particular it illustrates very well how a geological photograph can be manipulated so as to prove any desired theory. A view of the lower half only of Fig. 5 shows quite clearly that the schist must underlie the limestone, whereas if the upper strip of schist is included it is obvious that it cannot do so. The true direction of the contact is shown by the dotted line in the right-hand half of the figure.

As so often happens, it is clear that here the originally soft and yielding shaly beds of the Triassic rocks have been much more crumpled than the limestone. It may be mentioned that at one point as much as 100 feet of schist was seen, forming a nearly vertical portion of the cliff, with the limestone overhanging considerably above it. Further, the metamorphism has been intense: sufficient material for a petrographical description is hardly available, though a number of thin slices were cut for me at Batu Gajah. These include biotite-schist with quartz and tourmaline; biotite-pyroxene-scapolite-schist; quartz-pyroxene-schist; and garnet-idocrase rock. Most of these contain a certain amount of cassiterite, together with sulphides and often carbon. The whole assemblage is very interesting, and should be investigated further. It is clear that the schist series here was originally somewhat calcareous.

The other locality to be described is Changkat Papan, about a mile north-east of Sungei Siput, in the valley of the Sungei Depang, half way between Gopeng and Kampar. The eastern face of Gunong Tempurong (2,005 feet) here forms an enormous cliff of limestone, of which the lowest 1,200 feet or so are vertical. All the country to the east is granite of the Main Range batholith. At the foot of the great cliff are some small tin mines working in the bottom of the gorge, and a short distance up the north-east slope. In the narrowest part of the gorge granite and limestone are seen very near together, but above is a small area where schists come in, forming a sort of basin. The rock as seen in the chief exposures, when only slightly weathered, is a typical grey-blue phyllite, much slickensided and sheared, but as a rule it is decomposed to a dark blue clay, in which the structure is still preserved. In a small gully limestone is exposed, the top being impure and schistose, and immediately above it is phyllite. In a mine excavation a little higher up there are to be found embedded in clay and wash numerous boulders of very hard schist, perfectly preserved and ringing under the hammer. These appear to be core-boulders of the usual kind, and include some very interesting rocks.

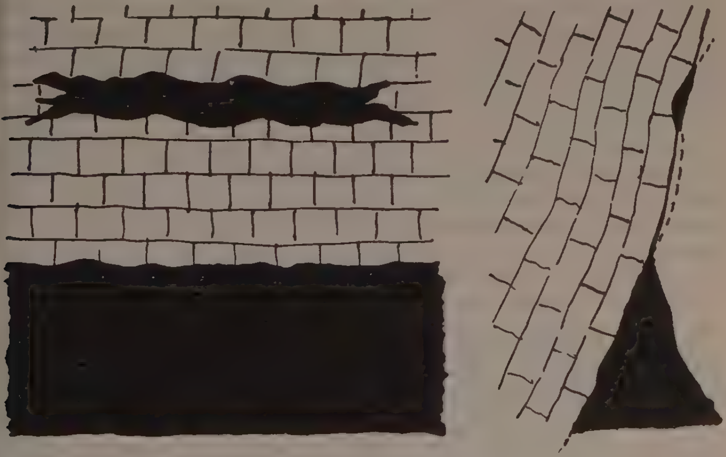

Fig. 5.—Front view (left) and section (right) of limestone-schist contact at Gunong Terendum.

Note.—In the left-hand figure, the stippling to indicate limestone is purely diagrammatic, since the surface shown is in reality one bedding plane. In the right-hand figure the stippling does represent the actual bedding.

On one occasion Mr. Willbourn and I followed the base of the eastern cliff for a long distance to the north in the endeavour to find the actual junction of the schist and limestone. In this we were not successful, owing to the great amount of detrital material and the thick jungle, but we found a great variety of blocks of schistose rocks of all kinds, showing an extremely high grade of metamorphism. Curiously enough the limestone is not very crystalline here, and I am inclined to suspect the existence of a great fault along this line, but it is clear that here also there is a wedge of schist along the granite-limestone contact, as at Gunong Terendum. It is not possible to make out the relation of the granite to the other rocks.

In places the folding of the schists is very intense, sharp anticlines and synclines having a wave-length of 3 inches or so. It is noticeable that exactly the same kind of brown and white quartz-tourmaline-schist is found in the Tanjong Tualang district on the other side of the valley, also as core-boulders in the weathered schists.

The conclusion that I draw from my observations at these two localities is that the limestone-schist junction here is approximately vertical, possibly faulted in some places, but representing the steep middle limb of a great asymmetric anticline due to a powerful thrust from the west, and therefore not due to the intrusion of the Main Range batholith, but of a later date. At Gunong Terendum the schist and the limestone may well be conformable, while at Changkat Papan, owing to a possible fault, the relation is obscure. The significance of this great fold will be discussed again in a later section.

V. THE WESTERN BOUNDARY OF THE LIMESTONE.

This is a subject which so far as I am aware has not received very much attention. In 1913 Mr. Scrivenor assumed a faulted junction of the Kledang granite and limestone on the eastern side of the range,[1] and the same is repeated in the memoir of 1919. In 1913 he also put forward some very interesting facts concerning the Tronoh mines.[2] The views of Mr. Cameron as to the existence of an " upper limestone " in this area have been already dealt with, and dismissed as untenable.

I have made a considerable number of observations of the relations of the rocks in the mines along the line of country extending from a little north of Menglembu, by Lahat, Papan, Pusing, Siputeh, and Tronoh, and from these I have drawn certain conclusions here offered for what they are worth.

To the east of this line, which runs approximately a little west of the branch railway line from Ipoh to Tronoh, extends the plain of the Kinta Valley, floored by pinnacle limestone. To the west of it is the Kledang Range, which, however, dips under the Triassic rocks and dies away to the south, being represented by scattered cupolas and dykes of granite intrusive into the schists. Along this line are an enormous number of mines, which work mainly masses of schist and alluvium, that appear to be let down into a sort of trough between the limestone and the granite. The great Lahat mine affords a typical example. The western face of this mine, about 350 feet high, consists of granite with a thin skin of schist: the part excavated consists of alluvium with masses of peat, while the very steep eastern wall conceals pinnacles of limestone. In mining such a deposit exposure of the limestone is avoided as far as possible owing to the danger of sudden rushes of water from the open joints, which often cause great expense in pumping.

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[1] *The Geology and Mining Industry of the Kinta District*, 1913, p. 18.

[2] Ibid., pp. 66–8.

A very striking example is afforded by the Kay Yew Mine, Sorokai, about a mile north of the Lahat mine, where there is a vertical face of limestone about 100 feet high, and I am informed by Mr. F. H. Nash that this extends also a considerable distance downwards, below the present floor of the mine. This limestone face seems to be an undoubted fault-scarp.

At the Keat Hock Tong Kongsi, at Pusing, which I visited with Mr. Nash, the relations seem to be the same. Limestone was not seen in place in the lombong at that time, though a very large loose block had been found in the alluvium. But pinnacles are very numerous close at hand, within a hundred yards or so, and they even stick up through the roads in the village of Pusing. One side of this mine consists of granite and the other of alluvium, but at the bottom is a wedge of schist decomposed to blue clay and very rich in tin.

The geological structure of the great Tronoh mine also appears to be of the same general type: the feature which has somewhat unfortunately been described as the "Tronoh lead" is essentially a great trough of a very similar character. Its western side is composed of decomposed schist, still preserving its folding and foliation perfectly, although converted to soft clay; it is also cut by numerous dykes and apophyses of a fine-grained aplitic granite. On the eastern side of the trough limestone pinnacles occur in abundance, at any rate at a small depth below the surface.

The main difference here is that the west wall of the trough consists of schist with only small intrusions of granite, instead of a solid mass of granite. This is what might be expected since the Kledang batholith in this latitude has sunk far below the surface; even the top of the pass on the Parit road consists of unmetamorphosed quartzites and shales, as also do the hills to the south. Here and there, however, are small masses of granite in the low ground, even as far as Tanjong Tualang.

I would like to draw special attention to the fact that long ago Mr. Scrivenor described and figured a great overthrust fault along the line of the Tronoh trough.[1] Unfortunately the evidence for this is no longer visible.

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[1] Loc. cit., p. 67.

The conclusion to be drawn from these observations is that along the western side of the Kinta Valley for a good many miles there is a great fault or system of faults, which, broadly speaking, bounds the foot of the Kledang Range and is continued to the south beyond the point where the range disappears. At some period of its history the line of this fault-system seems to have been marked by a great open trough, in which vast quantities of alluvium and peat accumulated, with much concentration of tin ore, giving rise to very rich deposits, now worked in many important mines.

VI. THE THICKNESS OF THE LIMESTONE.

It has been already stated that in the Langkawi Islands in the north-west of Malaya, the limestone is estimated to be 5,000 feet thick; here the base is visible, with Lower Carboniferous strata below. It is of interest to see whether any information can be obtained as to its thickness in the Kinta Valley. Frankly there is very little evidence obtainable. The highest of the limestone hills rises to about 2,000 feet, but as before explained, it is probable that this forms part of a fold with a vertical middle limb, so that this figure does not really give us a minimum. However, there is no evidence in this hill for a really complicated system of folds, repeating the sequence again and again; it is much more likely to be a fairly simple asymmetric anticline, since the dips on the western side of the hill are slight. It therefore seems likely that the thickness is to be measured in thousands of feet, rather than hundreds. Further than this it is impossible to go on these data.

There is, however, another line of argument which might possibly be made to yield some information. It is evident that it would be a matter of interest if some idea could be obtained of the depth of the granite-limestone contact at some distance from the margins of the ranges, or even in the middle of the valley. It is improbable that for a long time to come at any rate, deep bores will be put down in the plain, since so far as can now be seen there is nothing to be gained by such costly operations.

So far as I know the only thing of the kind that was ever carried out was a bore-hole south of Lahat, which penetrated 600 feet of limestone without reaching its base, and this is not very far from the granite margin.

General field work shows very clearly that the limestone near the granite contacts on both sides of the valley has been metamorphosed to a marble of very coarse grain, and that on the whole the size of the grain decreases rather rapidly away from the contacts. It seems a fair assumption that the average size of the grain is proportional to the distance from the nearest part of the granite, though there is always the possibility of disturbance by faulting. With this idea in mind I made a traverse across the valley from Lahat towards Pulai: along this road exposures are unfortunately not very numerous, but eight specimens were collected. It is perhaps worth mentioning that in the map published by Dr. Jones[1] the area thus selected for collecting a representative series of the limestone is indicated as occupied by schists and quartzites.

From these specimens slices were cut at Batu Gajah and the average size of the grains of calcite measured by means of an eyepiece micrometer in the microscope. The figures thus obtained were then plotted against the distances from one end of the traverse on a suitable scale, and a curve drawn through the points thus obtained. The result is shown in Fig. 6. The results are, of course, only approximate, but the curve has a very decided form, and certainly suggests a steeply plunging contact. One or two of the specimens from the middle of the traverse are only very slightly altered and show what are unmistakably fragments of crinoid ossicles, while at the ends there are exceedingly coarse marbles.

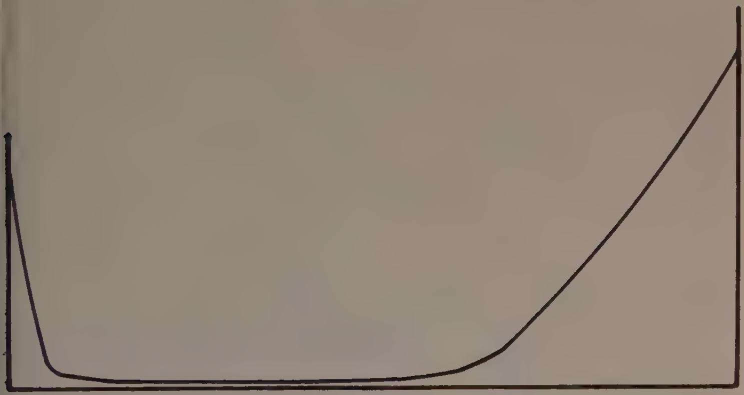

Fig. 6.—Curve obtained by plotting average size of grain of limestone against distance from granite contact, as explained in text.

Unfortunately, towards the eastern end specimens are few in number, and there is a long gap between Gunong Kroh and Kramat Pulai, so that this part of the curve is rather unsatisfactory. The western end is better, but there is the probability of some interference by the great fault along the foot of the Kledang Range, as before postulated (see p. 426). But the practical effect is much the same whether the granite and limestone are separated by a fault or a very steep contact, and it seems probable that over the floor of the valley, the granite lies at a considerable depth. That it does underlie the floor of the valley is indicated by the occurrence of stanniferous pipes in the limestone, as at Lahat and Pengkalen, and on the

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[1] Jones, *Quart. Journ. Geol. Soc.*, vol. lxxi, 1916, pl. xv. "Tinfields of the World," fig. 47, p. 170.

Malayan Tin Dredging Company's land, still further from the margin. Now as a rule such pipes occur not very far from the granite, and their existence rather goes to prove that at these points the granite is not at a very great depth. Thus the evidence on the whole is contradictory. However, the whole thing is very speculative, and is given for what it is worth. It is at any rate an interesting line of inquiry, which might ultimately prove to be of value.

VII. The Problem of the Limestone Hills.

The most striking physiographical feature of the Kinta Valley, as well as of other parts of Malaya to the west of the Main Range, is the great development of hills of limestone, of great height and extraordinary steepness. One of the highest and steepest of these, which I have only seen from the railway, is near Taiping, but those in the Kinta Valley, which I have had an opportunity of examining in some detail, are sufficiently striking. For example, the eastern face of Gunong Tempurong, above Changkat Papan, is more or less overhanging for the first 1,200 feet of its height, the summit being 2,005 feet above sea-level. The eastern cliff of G. Terendum, which I also examined carefully, shows a tremendous amount of overhang at the base, and there are many others nearly as striking. Some of them also stick up out of the plain in an apparently very arbitrary manner, but it is hoped to show later that there is some method about their arrangement in Kinta. It is noticeable that there are none for a long distance from the foot of the Kledang Range, while near the Main Range they are very numerous and very high.

These hills present so many features of interest that it is difficult to know where to begin. Apart from the peculiarities of their distribution perhaps the most striking points are their height and steepness; the decided overhang of many of them; the effects of solution and undercutting round their bases, with formation of caves; the enormous development of secondary calcite (stalactitic and stalagmitic) not only at the base and in caves, but on almost all exposed faces; and the occurrence in some of them of pronounced folding and faulting.

No further reference will be made here to the fissure-fillings with tin ore which occur in some of them, e.g. Gunong Lanno and the Jehoshaphat mine. This type of deposit has been sufficiently described by Mr. Scrivenor,[1] and I have not myself actually seen any of them in place. Such specimens as I have seen of the material from these fissures obviously represent detritus from some highly quartzitic formation, doubtless the Triassic rocks that originally overlay the limestone.

When the distribution of the limestone hills is studied on the map of the Kinta Valley, it soon becomes apparent that they comprise three sets. Furthest to the west is the small group immediately to the north-north-east of Ipoh, stretching from Gunong Lang to Gunong Tasek. I have not paid much attention to this group, but Mr. Scrivenor has pointed out that the trend of their elongation is parallel to the Kledang Range[1]; as will appear later, this is probably a point of considerable significance.

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[1] *The Geology and Mining Industry of the Kinta District*, 1913, p. 53.

Next comes a remarkable straight row of hills, from G. Kantang and G. Kuang, beyond Chemor in the north, to Temiang, Bercham, Tambun, Ginting, Panjang, and Rapat. This line is absolutely straight and stretches over some 15 miles. Along this line there is some very conspicuous folding. The best known example is the great overfold in the southern portion of Gunong Ginting, which is so clearly seen from the main road from Ipoh to Tambun, about half a mile from the last-named place, and also very well from the Tambun-Ampang road, over the top of a grove of coconuts. This is a very striking view. About 2 miles due south of Gunong Ginting, in the Yau Yok Choo mine, Lot 11589, is a very remarkable example of complex folding in the limestone of the plain at a low level. Unfortunately this has now been partly cut away to make room for a new engine house and palong, so that it is now difficult to make out, but by comparison of the present exposure with old photographs, it seems clear that there were at least two strong folds, and that the nose of a later overfold from the west has been thrust into and broken up an earlier and very steep fold. This is the same locality as was described on p. 418 in connexion with a thick shale-band in the limestone.

The northern face of Gunong Rapat, near the Ipoh Swimming Club pool, seemed to be the obvious place to look for a continuation of this line of disturbance. In order to save time, Inche Mayah bin Latib, of the Geological Department of the Federated Malay States, went to make a preliminary survey: he brought back specimens showing strong folding in the limestone, and I therefore visited the place with Mr. Willbourn and Dr. Ingham. We found that the limestone is here very much disturbed, that the bedding is on the whole vertical, with numerous minor folds; and that vertical faults appeared to be predominant over folding on a large scale, though the rock is much crumpled locally. Since my departure Mr. Willbourn has again visited the place and found much faulting further into the hill. According to the map there is inside it a peculiar kind of amphitheatre, as to which I have no information. It is at any rate clear that there is here an important area of disturbance, and "the whole of the northern cliff face of this hill suggests the middle limb of a big asymmetric anticline", as recorded in my field notebook.

It appears, therefore, that taking this line of hills as a whole, there is evidence of a strong thrust from the west, forming an asymmetric anticline with its steeper limb to the east.

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[1] Ibid., p. 18.

We now come to the immense mass of limestone hills that border the eastern side of the valley, at the foot of the Main Range. So far as I know the highest of these is Gunong Tempurong, 2,005 feet, but some others exceed 1,500 feet. Of course, in absolute height they are far overshadowed by the granite peaks of the Main Range, which run up to over 7,000 feet, but as scenery they are very striking. The series begins in the north with Gunong Laiang-Laiang, 950 feet, between Tanjong Rambutan and Tambun; the next, 1,370 feet, appears to be nameless: then comes the enormous mass behind Ampang of which G. Datoh forms the northern part, 1,520 feet; G. Terendum, 1,500 feet; G. Lanno, 1,332 feet, and its outlier south of Kramat Pulai; beyond this point the hills become lower; such as G. Kandu, 640 feet, south of Gopeng, but the height rises again in the vast mass of which the southern end of Gunong Tempurong, 2,005 feet, is the culminating point, overhanging Changkat Papan (see p. 423). South of this there are no more for a long distance. Immediately to the south of G. Tempurong, the great granite mass of Bujang Melaka, 4,070 feet, advances far to the west of the line of the granite boundary to the north of it, and appears to break off the line of the limestone hills; but the type reappears again at the Batu Caves in Selangor, near Kuala Lumpur. This, I believe, is the most southerly example.

As already explained in an earlier section of this paper, I have examined with some care the eastern faces of Gunong Terendum and Gunong Tempurong, as typical examples of this line of hills, with special reference to their relation to the schist series. From these studies it appears that in these cases the eastern cliff-faces indicate that the stratification of the limestone is overfolded towards the east, as shown by the dip of the limestone-schist contact. It is probable that the same relation will be found to hold in the other hills, though time did not allow of a verification of this.

The first conclusion to be drawn from the observations set out above is that the limestone hills mark the positions of three axial lines of folding in the form of asymmetric anticlines overturned towards the east. Even apart from detailed study of dip, strike, and folding, it is perhaps worth mentioning that in a general view nearly all the hills give the impression of being tipped over towards the east. This is even true of the distant view of the Ipoh group as seen from the top of the Kledang Range.

But it is evident that folding alone is not able to account for the very disconnected distribution of the hills, especially those of the middle line, which rise at long intervals with remarkable suddenness from a nearly flat plain.

This subject has been very completely studied by Mr. Scrivenor, who attributes the existence of the hills mainly to faulting. I agree with Mr. Scrivenor that faulting has played a very important part in their formation, but I do not hold the view, which seems to be implied in his discussion, that the upper surface of the limestone in general once formed a high-level surface over the whole area, at a height above the present tops of the hills. I believe, on the contrary, that there were once three anticlinal ridges with low-lying areas between them, and that these ridges were cut up and modified by faults in different directions, and by subsequent denudation.

The geological map of the Kinta Valley shows that between the second and third lines of hills, around Tambun and Ampang, and, northwards, there is a large area of rocks of the "schist series" at a low level, which is known to rest on limestone, as for example, at the Rambutan, Ltd., mine (see p. 420). This relation can be explained either by folding or by block-faulting of the rift-valley type, or by a combination of the two. There is as yet not sufficient evidence to decide which it is.

Since the probable positions of the chief lines of faulting have been dealt with in much detail by Mr. Scrivenor, it is unnecessary to go over it all again. So far as I can see, Mr. Scrivenor's fault system is just as applicable to a series of three parallel anticlines striking nearly north and south, as it is to a solid plateau of limestone. It is very difficult to form an opinion as to whether the eastern faces of the hills are fault-scarps, or whether they are determined by the vertical or overturned middle limbs of folds. This difficulty is very largely due to the enormous development of stalactitic calcite as before mentioned, which usually obscures the dip and strike even in large vertical faces, and of course it is obvious from the foregoing descriptions that the hills are in any case very difficult of access, except by monkeys, which are abundant on many of them.

On the supposition that there are three lines of folds, striking roughly north and south, and overturned towards the east, it remains to consider what may be the relation of these to the general tectonics of the district. Such a structure naturally implies a great thrust from the west; from the Kledang Range towards the Main Range. It is obvious that it cannot be due to the intrusion of the Main Range batholith, which seemes to have acted as a horst, and the nference is, to put it shortly, that the Kledang Range is later than the Main Range, its uplift and intrusion being due to earth pressure coming from the west and crumpling the rocks against the already solidified and rigid Main Range batholith. It is not possible here to enter on a far-reaching discussion of the general tectonics of the Malay Peninsula, but there appears to be in this idea nothing nconsistent with the generalizations of the geologists of the Netherlands East Indies on the tectonics of the whole area.[1]

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[1] Brouwer, *The Geology of the Netherlands East Indies*, New York, The Macmillan Company, 1925, p. 46, and bibliography. Scrivenor, "The Structural Geology of British Malaya," *Journ. Geol.*, vol. xxxi, 1924, pp. 556, 570.

VIII. Summary and Conclusion.

The following is a very brief summary of the results of my investigation of the problems here dealt with :—

(1) The limestone is Carboniferous or Permo-Carboniferous or more probably both.

(2) All the limestone belongs to one continuous phase of deposition.

(3) The " Schist Series " is above the limestone, and is of Triassic age.

(4) The western boundary of the limestone is a great fault or system of faults.

(5) The thickness of the limestone is indeterminable, but is probably to be measured by thousands of feet.

(6) The limestone hills are due to overfolding from the west, modified by block-faulting and denudation.

In conclusion I would like to express my deep gratitude for the help and kindness that I received during my visit to the Kinta Valley from Mr. Scrivenor, the Government geologist, and all the members of the staff of the Geological Department, both European and Malay. As was natural in the circumstances of a short visit, either Mr. Scrivenor or Mr. Willbourn accompanied me in the field on nearly all occasions ; otherwise much time would have been wasted ; but they merely showed me the evidence, and left me to draw my own conclusions on controversial matters. In the later stages of my investigations, much profitable discussion and criticism was forthcoming from them, and in final visits to some sections, I was accompanied by Dr. Ingham, who only arrived in Malaya about a month before my departure. I am greatly indebted to Inche Mayah bin Latib, who was specially detailed to attend me, and did some useful preliminary work for me in various localities. I have also to thank Mr. F. H. Nash, of the Mines Department, Kinta, for useful hints and discussions. I am indebted also to the Editor of the *Mining Magazine* for kindly allowing me to reproduce the two maps illustrating this paper.

It was a great help to rapid field work that it was possible to have microscopic sections of rocks cut at Batu Gajah within a few hours of their collection. The Malay collectors are very skilful at this work.